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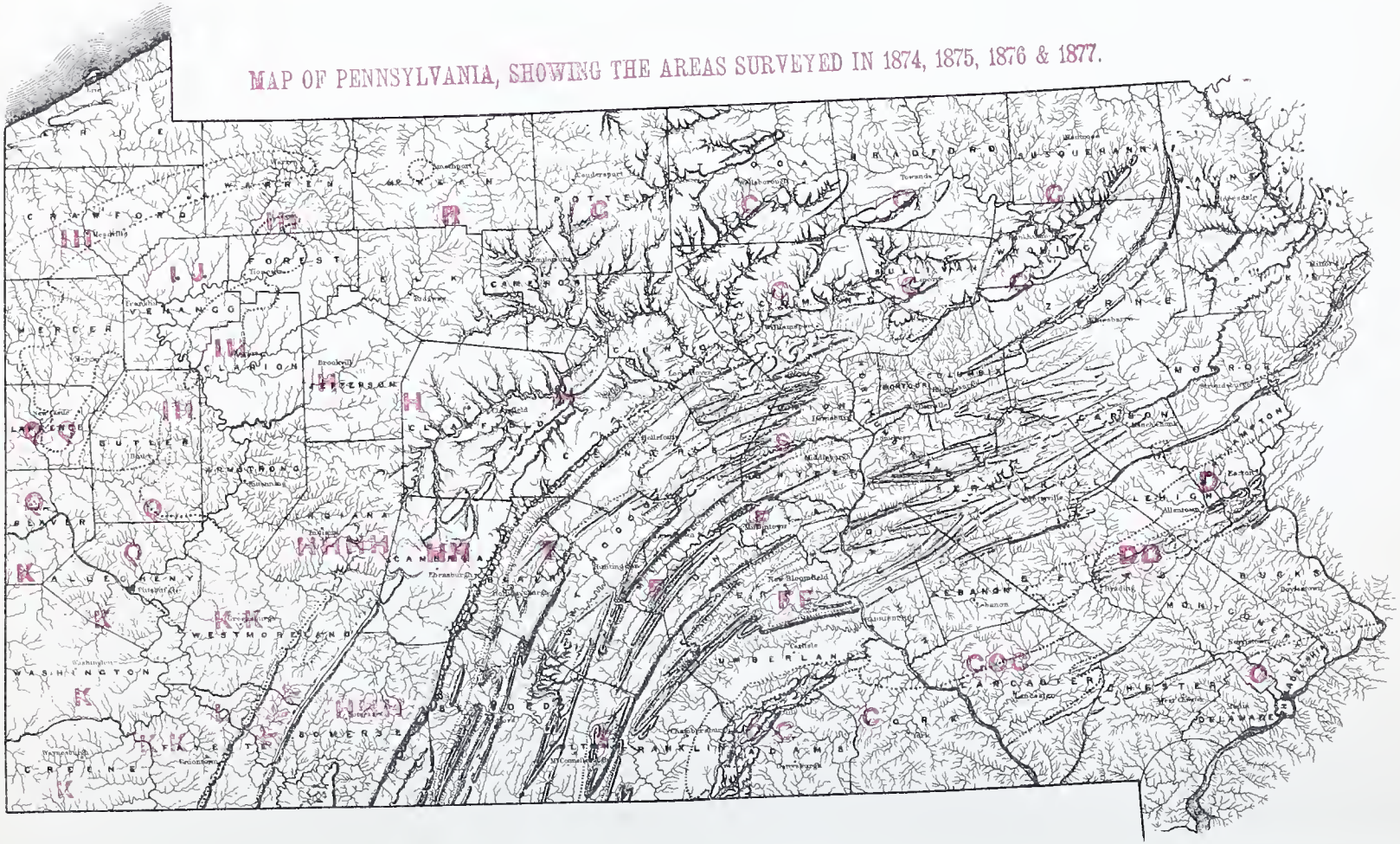
MAP OF PENNSYLVANIA, SHOWING THE AREAS SURVEYED IN 1874, 1875, 1876 & 1877.



SECOND GEOLOGICAL SURVEY OF PENNSYLVANIA:
1874–78.

REPORT OF PROGRESS

IN

BRADFORD AND TIOGA COUNTIES.

1. Limits of the Catskill and Chemung Formations.

By Andrew Sherwood.

2. Description of the Barclay, Blossburg, Fall Brook, Arnot, Antrim and Gaines Coal-fields, and at the Forks of Pine Creek in Potter County.

By Franklin Platt.

3. On the Coking of Bituminous Coal.

By John Fulton.

Illustrated by 2 colored geological county maps;
3 page plates and 35 cuts.

HARRISBURG:
PUBLISHED BY THE BOARD OF COMMISSIONERS
FOR THE SECOND GEOLOGICAL SURVEY.

Entered, for the Commonwealth of Pennsylvania, in the year 1878, according to acts of Congress,

By JOHN B. PEARSE,

Secretary of the Board of Commissioners of Geological Survey,

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615 Walnut Street,
Philadelphia, *December 31, 1877.*

Prof. J. P. Lesley,

State Geologist:

Dear Sir: I submit to you herewith my Report on the Coal Basins of Bradford and Tioga Counties.

In accordance with your instructions I interrupted in August last the examination of Blair County, and spent the remainder of the season in the Barclay, Blossburg, and Gaines Coal Basins.

For the accurate vertical sections of the coal measures in the basins, and for outline maps of the basins themselves, the Survey is indebted to Messrs. E. M. Davis and Harvey Shaw, the President and Treasurer of the Barclay Coal Company; to Mr. F. F. Lyon, Mining Engineer, and Mr. McCraney, Superintendent of the Towanda Coal Company at Barclay; to Mr. J. B. Judd of the Barclay Coal Company; Mr. Hardt, Engineer of the Fall Brook Company; Mr. Neering of Mooris Run; Mr. Elliott of Arnot; Mr. Billings of Gaines; Mr. Henry Baker of Sabinsville; and most especially to Mr. James Macfarlane of Towanda.

I remain, Sir,

Very respectfully yours &c.,

Franklin Platt.

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PREFACE.

The first part of this volume contains the substance of Mr. Sherwood's notes,* according to which he defined by colors, on the best township maps of the two counties that he could find, the limits of the areas occupied by Catskill and Chemung rocks; locating also with approximate correctness the outcrop lines of the Mansfield iron ore beds.

The colored maps of the two counties accompanying this volume were prepared from the township maps above referred to. They are of course very imperfect; as all illustrative maps so constructed must be; serving no other purpose than to guide in a general way the traveler and explorer to their places of research. Nothing better can be published until the Legislature is aroused to the importance of an accurate geodetic or topographical survey, based upon a triangulation of the State, and furnishing for the use of county surveyors one or more absolutely true fixed points in every township.

The beauty of the maps accompanying this report will be acknowledged. A peculiar symmetry of feature characterizes them. The basis of this symmetry lies in the geology, and is exhibited by the coloration. One can see at glance that both counties are traversed by long, low, flat-topped, narrow and parrallel mountain ranges, terminating abruptly on a surrounding plain; each range projecting further towards the east than its left hand neighbor on the north.

These mountains, when viewed geologically, are troughs; in which lie the mountain rocks; and on their summits

*I ought in justice to Mr. Sherwood to state that I have so modified, condensed, and expanded his notes that he can not properly be held responsible for much of the text of the report.

small fragmentary coal fields, which have been saved from destruction along those comparatively sheltered lines.

The second part of this volume is a report from Mr. Franklin Platt, describing these coal fields.

Mr. Platt has made a special study of the lower coal measures lying back of the Allegheny mountain throughout its length across the State; that is, in Somerset, Cambria, Clearfield, Jefferson, Centre, Clinton, Lycoming, Sullivan, Wyoming, Potter, Tioga and Bradford counties; and he therefore brings to the study of the coal fields of these counties a knowledge both copious and exact.

He has had the advantage of consulting numerous private and unpublished maps and reports of coal tracts on the Towanda and Blossburg mountains. Some of those maps it was my intention to present with this report. But they are so large and elaborate, and the demands of the survey in other parts of the State have been so exacting, that their publication has been postponed until the appearance of another volume, containing Mr. Platt's report on the small coal fields of Sullivan, Lycoming, Potter* and Clinton counties, now in preparation.

Some difficulty was experienced in portraying with their exact shapes the numerous patches of coal measures strung along the summits of the high lands in the Barclay (or Towanda) field and in the Blossburg basin west of the Tioga river, upon the county maps; and that from various causes:

1. Because the detailed surveys of the coal lands have commonly been limited by the outcrop of the lowest workable coal bed. The outcrop of the Pottsville Conglomerate No. XII, extends irregularly beyond and encloses the patches of workable coal; and sometimes extends, over what is practically worthless land, so far, that a very false idea of the workable coal areas would be conveyed to the reader if the outcrop of the Conglomerate be alone considered.†

* One of the Potter county tracts however is described in this volume, in connection with the neighboring Gaines coal field in Tioga county.

† Thus, it is well known that the *workable* coal beds are confined to the mountain tops *north* of the Schroeder. Yet coal measures lie on those *south* of the Schroeder.

It cannot be too often repeated that these colored county maps are merely illustrations intended to make the text of the report comprehensible. The carefully constructed local survey maps, on the contrary, are in themselves reliable statements of facts, and subserve purposes of measurement.

2. Because the local survey maps have been made by various geologists and mining engineers, at various times, and for independent coal companies; so that no complete instrumental survey on a large scale has been made, either of the whole Blossburg trough, or of the whole Barclay trough. Nevertheless a published colored map can only be printed from stones in such a way as to convey the impression of connexion and continuity everywhere alike.

3. Because the edge of the Conglomerate is often a vertical cliff, forming the cornice of a mountain wall descending abruptly into a valley or ravine. The Mauch Chunk red shale No. XI is thin, and so completely covered by the Conglomerate as to make no show upon a map of so small a scale as 2 miles to 1 inch unless it be exaggerated. In other places where the Conglomerate has been eroded from broad mountain summits of Pocono Sandstone, No. X, these summits are covered by a thin coating of red shale which makes a great show upon the map. Indeed the very existence of any noteworthy thickness of red shale beneath the Conglomerate has not been proved in the case of the Tioga mountain, where, nevertheless, rings of red color may be seen upon the map surrounding the Gaines coal patches, and the small patch of conglomerate north west of Wellsborough. It must also be remembered that there is often a thin layer of coal under the Conglomerate.

A great error has been committed in preparing the west border of the Bradford County map and the east border of the Tioga County map. It may be seen at a glance that the coal area in Armenia township is much too large to fit on to the coal area of Ward township, and that the red ring of No. XI on the Tioga side of the county line shows no continuity with the red ring of No. XI on the Bradford side of the line, except on the northern side.

The fact is, no survey of the Armenia mountain top has ever been made, because no workable beds of coal are known to exist in it. A large, irregular, much eroded plate of conglomerate covers it, the exact edges of which are unknown; and therefore the exact place and breadth of the surrounding belt of red shale is also indeterminate.

Another error has been committed in omitting the red border (of XI) from the patch of conglomerate lying south of Blossburg.

A third anomaly is noticeable on the Bradford map, but chargable to some misunderstanding or neglect of instructions by the artist who made the last corrections on the color stones:—not only is the color for Pocono Sandstone, No. X, *outside* of the red belt of No. XI, in the Barclay coal basin, used for the conglomerate No. XII area *inside* that belt, but, the edges of the coal patches are allowed to touch and even sometimes to overlap the red belt, leaving no room for the outcrop of the Conglomerate between them.

Finally, it may be noticed that two belts of the red color assigned to the Catskill No. IX are made to traverse the north east townships of Bradford county, and are united into one belt, west of the river, in Smithfield and Burlington townships. How much of the areas thus colored is really Catskill, and whether all of the two belts east of the river should not be colored Chemung, is a doubtful point, explained in the report under the head of the Red beds of VIII. Further surveys in Susquehanna County may settle the question.

The third part of this volume contains a carefully prepared statement of the best methods of coking such coals as occur in the counties under review, by Mr. John Fulton of the Cambria Iron Works, to whom we owe, among other contributions to the Survey, the report on coke published in Report of Progress L, 1876, pp. 117 to 146.

J. P. LESLEY.

PHILADELPHIA, *Dec. 1, 1878.*

CHAPTER I.

GENERAL DESCRIPTION OF TIOGA COUNTY.

Tioga is the fourth county of Pennsylvania in the northernmost tier of counties, on the New York State line, counting from the north-east corner of the State and Delaware river; the first being Wayne; the second, Susquehanna; the third, Bradford and the fourth Tioga. Potter county comes next to it, continuing on westward. Lycoming county lies to the south of it. Steuben county, in the State of New York, lies north of it.

Tioga county has a regular shape, being nearly square. Its *north* line, being also the State line, was run upon the parallel of north latitude 42°. Its *south* line was intended to follow the parallel of 41° 35′. Its *west* line was laid along the meridian of 0° 47′ west from Washington. Its *east* line runs a little east of south, from a point on the State line about 0° 2½′ east of the Washington meridian to the marsh* at the head of Lycoming creek, between Canton and Ralston; whence the county line descends Lycoming creek five miles and ascends Roaring brook about three miles, thus cutting off the theoretically square south-east corner of the county.

Its north line is therefore about 34½ miles long.
Its south line (if straight to Lycoming creek) 33¼
Its west line is 31¼ miles long.
Its east line is 28¼ miles long.
Its south-east line (on Lycoming creek) 5.
Its area is therefore about 1,125 square miles.

*Towanda creek may be said to head also in this marshy divide in the bed of the deep valley.

Tioga county is sub-divided into twenty-six townships, arranged in the following order:

Brookfield.	Deerfield.	Osceola. Nelson.	Lawrence.	Jackson.
Westfield.		Farmington.		
	Chatham.		Tioga.	
Clymer.		Middleborough.		Rutland
			Richmond.	
Gaines.	Shippen.			Sullivan.
			Covington.	
	Delmar.	Charleston.		Ward.
Elk.			Bloss.	
	Morris.	Liberty.		Union.

Some of these townships have a well cultivated surface; others remain still in a wilderness condition, upon land two thousand feet above the sea, and covered with forest. The smaller townships have the densest population. The large size of a township upon the map is sufficient indication of a rocky, forest covered soil, and a scattered population of hunters, miners and lumbermen.

The Allegheny Mountain Plateau of Potter and Lycoming Counties begins in Tioga County to break up into parallel flat-topped mountains, supporting in shallow basins several isolated coal fields, and numerous smaller coal patches. These synclinal mountains are separated from each other by broad anticlinal valleys of Devonian rocks: Chemung (VIII) and Lower Catskill (IX). Culture is confined to these valleys, and the villages and towns are situated in them; while the steep mountain slopes and broad tops are covered with forest, and often with continuous sheets of angular blocks of the Conglomerate (XII), the edge of which forms continuous lines of vertical cliffs from 50 to 100 feet high, gashed with chasms and crowded with rattlesnakes.

Three such mountain ranges penetrate into and two of them pass through the county in a direction about N. 60° E. and a fourth just touches its south-east corner.

The south-west corner of the county is part of the general Potter-Lycoming Allegheny Mountain plateau cut through to its base by the cañons of Pine Creek, and over this spread the townships of Elk, Morris and Gaines.

The first and principal mountain range is merely a projection of this plateau, N. 60° E., through Morris, Liberty, Bloss and Ward, ending roundly in Armenia township, Bradford county. The range is drained south-westwardly along its centre line (representing the axis of the synclinal, or deepest part of the trough) by the Second Fork (Babb's Cr.) of Pine Creek; and the extraordinary spectacle is here exhibited of several large streams from the Wellsborough Valley flowing *towards* the north face of the mountain, *entering it* and uniting with the main stream along its middle line.

The important bearing of this feature upon the theory of erosion, and the geological date of the formation of our whole mountain and valley system will be referred to again. This topographical phenomenon is repeated in the next mountain range to the north, and is an example on a small scale of a law much more grandly illustrated by the rivers of the State of Ohio, which flow into the Ohio river above and below Wheeling.

The eastern end of this first mountain range of Tioga county is a deep coal basin drained by the Tioga river, which breaks out from a gap in the north wall near Blossburg, and flows due north into the State of New York. The rim of the Blossburg Coal Basin (in Bloss, Ward, Armenia and Union townships) is the edge of the cup of the conglomerate, forming an unbroken ellipse of cliffs, from which the spectator looks down a thousand feet upon the broad valley of Mansfield and Wellsborough to the north-west; over the open rolling country of Bradford county to the north and east; and into the narrower valley of the Lycoming, separating the Blossburg from the Towanda mountain.

The second mountain range of Tioga county is a projection from the Potter county plateau, N. 70° E., through Shippen, Middleburg and Tioga townships, in which last it ends as boldly as the Blossburg range ends in Armenia township. Through its western mass Pine creek and its waters cut ca-

ñons nearly a thousand feet deep. In the middle part of its course the mountain receives from the Wellsborough valley on the south, and Chatham-Farmington valley on the north, several large streams which approach, enter and unite within and flow along the centre line of the mountain in a long cañon, splitting the mountain lengthwise into two. Further east the Tioga river cuts square through the mountain, isolating its eastern end. Steep slopes of sandrock (XII) form the rim of the flat top of the mountain, and the summit line of the cañon on both sides. Small patches of the lowest coal bed have been left along the summit, but all other traces of the Coal Formation have been swept away except in Gaines.

The third mountain range passes through the north-west corner of the county (Brookfield and Deerfield), and from it descend the branches of Cowenesque creek, which flows in a pretty straight line about N. 75° E. for fifteen miles, at its foot. No coal measures are left upon this mountain range, and the Conglomerate becoming comparatively fine-grained and thin bedded, does not furnish its top with the same remarkable cliffs. To this enfeebled condition of the Conglomerate is no doubt due the erosion of the overlying coal measures, and their absence from the State of New York.

Descending now from any part of the rim of cliffs at the top of either of the three ranges of mountains in Tioga county, the geologist climbs down a steep slope over the nearly horizontal edges of always one and the same system of rock formations. The surface geology of Tioga county is therefore monotonously simple to an extraordinary degree.

The lowest point in Tioga county is in the cañon of Pine creek, passing into Lycoming county below Lloyd's, at the mouth of Babb's fork, which is 833′ above tide. Marsh creek mouth is 1,106′; Mill creek mouth (Gaines') is 1,219′; and where Pine creek enters from Potter county its bed is nearly 1,300′ above tide; the summits of the coal-covered mountain tops to the north being over 2000′. Pine creek has a fall of twenty feet per mile for fourteen miles.

Tioga river leaves the county and enters New York State at an elevation of nearly a thousand feet, for the railroad grade at Lawrenceville on the State line is 1,006′; at Mitchell's creek

mouth, 1,022′; at Tioga village, 1,042′; at Mill creek mouth, (not the Mill creek before mentioned, which is in Gaines township,) 1,077′; at Lamb's creek, 1,111′; at Mansfield, 1,140′; at Canoe Camp, 1,163′; at Covington, 1,208′; and at Blossburg, 1,348′.

Tioga river descends, therefore, about 350 feet from Blossburg to Lawrenceville, in a distance of twenty-two miles, in a nearly straight line, (or twenty-five miles by its bends,) at the rate of about twenty-two feet per mile for the first nine miles, and eleven feet per mile for the last fourteen miles.

Tioga river falls 500′ in six miles above Blossburg, from the Fall Brook coal mines, which are 1,842′ above tide; and the mountain summit, back of the mines, rises several hundred feet higher. The end of the Arnot branch railroad is at 1,688′. The whole mountain top (Briar Hill, &c.,) spreads out at an elevation of something over 2,000′ above tide.

Crooked Creek cañon, which splits the second range, and issues at Tioga village, (1,042′ railroad grade,) has been engineered for a railway to the Antrim coal mines of the first or Blossburg range. This railway crosses the Wellsborough valley. At Hollidaystown its grade is 1,151′; at Middleburg Centre, (Niles Valley P. O.,) 1,179′; at Wellsborough, the county seat, in the centre of the valley, and on the crown of the anticlinal and divide between the waters which flow four ways, 1,317′. The railroad summit, in a low gap in the first range, is 1,862′; and at the Antrim coal mines, 1,672′. Antrim terminus and Arnot terminus are therefore nearly on a level with each other and with the Morris run terminus 1,678′.

Lycoming creek, which skirts the south-east corner of the county, flows at the same level as the Tioga river at Covington; the Williamsport and Elmira railroad grade at Carpenter's being 1,200′, and the Tioga railroad grade at Covington 1,208′; Canton railroad station is 1,250′; Minnequa, 1,230′; Granville Summit, 1,393′; Troy, (opposite the end of the Blossburg mountain in Bradford county,) 1,100′.

It is easy to see from the above figures that while the mountains of Tioga county rise to a pretty uniform general level of 2,000′ above tide-water, and the broad valleys between roll

their surfaces about 1,200′ or 1,300′, the main water channels are cut sharply down to depths of 1,000′ or even lower.

The streams are fed by abundant rains; for Tioga county lies in the rain belt of 40 inches. The mean annual rain-fall is 40 inches. While the mean summer temperature is 63°F., the mean winter temperature is only 23° F. The cold is therefore, for Pennsylvania, excessive.

Consequently the erosion of the surface, through the agencies of frost and rain, has been actively carried on through all ages since the Coal Era. Dry north-west winds favor radiation and evaporation, carrying down the temperature far below zero. They favor equally the full effect of the sun's rays upon the rock surfaces. The rocks, alternately expanded and contracted, are prepared for absorbing moisture; the frost breaks them, up and innumerable rivulets, periodically swollen, carry of the fragments and grind them into sand and mud. The forest, while it is a protection against this wear and tear in one sense, facilitates it also by prying the outcrop layers apart with their roots, and every surface, hill slope and mountain steep alike, is slowly but always creeping down towards the waterways.

It is this universal erosion, taking effect upon a large area of exceedingly regular stratification, which explains the beautiful regularity of the parallel ranges of mountains traversing the county, and the striking similarity of the broad valleys which run up from the open country of Bradford, westward, into and between the mountains of Tioga. It explains also why these valleys end or head up, each in the form of a wide amphitheatre, against the unbroken or undivided plateau of Potter and Lycoming counties.

The diagonal or *echelon* character of the whole series of mountains, due to another and strictly geological cause, will be best explained when, in the next chapter, the other mountain ranges in southern Bradford are described.

It is evident, then, that the mountains of Tioga county have in past ages been much higher than they now are. There is no good reason for doubting that the whole of the Coal Measures once covered this country. As the Coal Measures of Pennsylvania, both in the south-western corner of the State,

where more than 2,000 feet of them remain to be measured, and in the Anthracite Basins, which, in the deepest parts, hold 3,000 feet of them still undestroyed, may have been originally even 4,000 feet thick, it seems probable that the Tioga mountains were once as high as Mount Washington. Most of this great formation has been gradually carried away into the Atlantic Ocean. In the Blossburg Basin there remain several hundred feet of the lower Coal Measures holding several valuable beds. And this exception to the universal destruction is due to the fact that, around Blossburg, the trough which extends for a hundred miles through Bradford, Tioga and Lycoming counties, and is traceable still further to the north-east and to the south-west, is exceptionally deep in this part of its course, the coal in the bottom of it having been somewhat protected by steeper dips than usual on the sides, and by a somewhat greater breadth of bottom. Wherever this and the other parallel troughs are flat and shallow the coal beds, wanting this protection, have been gradually washed away.

But if in past ages the mountains have been several thousand feet higher than they now are, so also have been the valleys. In fact the valleys have suffered more from erosion than the mountains.

In fact, originally, the valleys were higher than the mountains. In spite of the singularity of this assertion, it is strictly true, and any inhabitant of Tioga county can verify the fact by his own observation.

It is only necessary to notice that, throughout Tioga county, all the rocks of every kind, and in every place, dip away from the middle lines of the valleys *towards*, *into* and *under* the mountains. The strata lie flat along the centre lines of the valleys, and also lie flat in the middle of each mountain range. But on the north face of a mountain they dip south, and on the south face they dip north, in all cases. There is even a very slight, almost imperceptible dip at the end of each mountain into the mountain. The rule is absolutely universal.

A cross section through Wellsborough along the railroad, or through Mansfield along the Tioga river, shows a broad, gentle arch or anticlinal; the strata dipping towards Blossburg and

Antrim in one direction, and toward Middleborough and Hollidaytown in the other.

So again in the valley of the Cowanesque, the rocks seen along the river dip south towards Tioga and go under the mountain at Crooked creek; and they dip north towards Lawrenceville and go under the mountain at Osceola and Elkland.

So again around Canton, the rocks may be seen dipping gently north-west into and under the Blossburg mountain, and also south-east into and under the Towanda mountain.

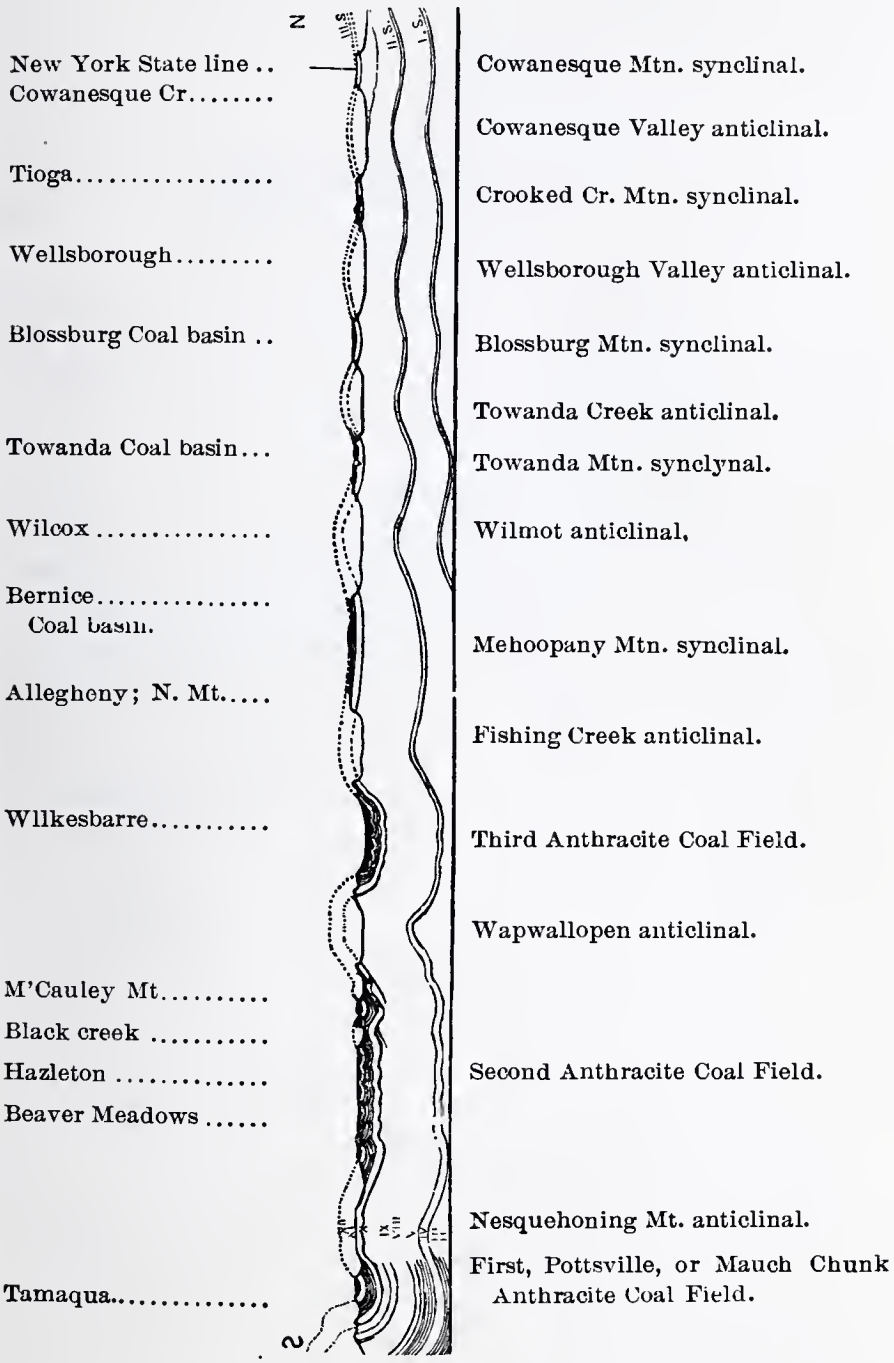
The rule is, then, that the valleys are arches or anticlinals, and the mountains are all troughs, basins, or synclinals. The following chapters of this report will take up these anticlinal valleys and synclinal mountains and describe them in succession from south to north.

If any one will draw the dips as they appear in a cross section of the county, the reason for saying that the valleys were once more elevated than the mountains, will become apparent without further discussion.

Figure 1 represents a combined skeleton cross-section,* extending from the north line of Tioga county, south-eastward at right angles to the anticlinal and synclinal waves, through Tioga, Sullivan, Luzerne, Carbon and Lehigh counties. It shows the large deep anthracite basins in its southern half, and the shallower and more elevated semi-bituminous basins further north. It shows that they all form parts of one system. It shows why the lowest coal beds are now on the mountain tops of Lycoming, Sullivan, Bradford and Tioga counties, while in Schuylkill and Luzerne they are sunk to depths of several thousand feet beneath the bottoms of the valleys; and also that the valleys of the north occupy the sites of what in former ages were the highest mountains. It shows moreover the thinning of the formations going north, and the gradual approach of the great sandstone formations to one another (in vertical distance) in the same direction. It shows why the valleys of Tioga county are formed wholly of the Chemung formation (part of No. VIII) and the mountain sides of Catskill (No. IX, X). And finally it explains the extreme simplicity and uniformity of the geology of the district under review.

* This section was not reversed in drawing it on the wood, so that it looks west instead of east.

Fig. 1. *Skeleton Cross Section in Northern Pennsylvania.*



The following names for the formations have been adopted for convenient use in the Reports of Progress of the Geologi-

cal Survey of Pennsylvania. They are chiefly taken from the Geology of New York:

No. XIII. Lower Productive Coal Measures.
XII. *Seral* Conglomerate.
XI. *Umbral* Red Shales.
X. *Vespertine;* Upper (White) Catskill.
IX. *Ponant;* Lower (Old Red) Catskill.
VIII. Chemung; with its Mansfield red-beds.
" Portage.
" Hamilton.
" Upper Helderberg.
VII. Oriskany.
VI. Lower Helderberg.
V. Clinton.
IV. Medina and Oneida.
III. Hudson river; Lorraine, Utica.
II. Trenton, and magnesian limestones.
I. Potsdam, resting on South Mountain rocks.

No mention need be made in this report of any of the formations beneath the Portage.

CHAPTER II.

GENERAL DESCRIPTION OF BRADFORD COUNTY.

Bradford is the third in order of the northern tier of counties in Pennsylvania from the north-east corner of the State.

Susquehanna county borders it on the east; Tioga on the west; Sullivan on the south, and Chemung and Tioga counties of the State of New York, upon the north. At the west end of its southern line a small border of Lycoming county occurs; and the north-west angle of Wyoming county enters its southeast corner.

Otherwise Bradford county is nearly a parallelogram upon the map. Its northern line is the State line, laid along the parallel of 42° north latitude. Its west line runs a little east of south to the head of Lycoming creek, as described in the last chapter. Thence its south line runs about S. 83° E. Its east line was run about upon the meridian of 0° 48½′ E. from Washington.

Its north line is about 40 miles long.

Its west line is about 27½ miles long.

Its east line is about 24½ miles long.

Its south line is about 33 miles long.

Its area measures about 1,145 square miles.

The re-entrant angle produced by the north-west corner of Wyoming county, is located on the Susquehanna North Branch midway of the second bend below Wyalusing. From this point a short east and west county line, four miles long, strikes the west county line of Susquehanna close to its southern end; and from the same point on the River, a straight line runs about S. 15° W. seven miles and a half to meet the east end of the south line of Bradford county.

The townships of Bradford county are 37 in number and arranged in the following order on the map:

Wells.	S. Creek.	Bridgebury.	Athens.	Litchfield.	Windham.	Warren.
Columbia.	Springfield.	Smithfield.	Ulster.	Seshequin.	Rome.	Orwell.
			N. Towanda.	Wysox.	Herrick.	Pike.
Armenia.	Troy.	W. B. Burlington.	Towanda.	St.	Stone.	
	Granville.	Franklin.	Monroe.	Asylum.	Wyalusing.	
Canton.	Leroy.	Barclay.		Terry.	Tuscarora.	
		Overton.	Albany.	Wilmot.		

The Susquehanna River enters the county midway of its northern boundary, and the Chemung River (flowing from the north-west and draining Central Southern New York) unites with it below Athens, and just five miles south of the State line. The Susquehanna River flows in about a straight line due south nearly to the centre of the county, and then takes a south-east course (with nine horse-shoe bends) until it enters Wyoming county.

During its straight course it flows in a rather wide valley of erosion in Chemung rocks. The rest of its tortuous course is through Catskill rocks, where it cuts a cañon through the synclinal Towanda Mountain and a deep narrow valley through the Chemung rocks, across the broad anticlinal valley to the south of it.

One-half of Bradford county is a high rolling hill country, into which enter two ranges of flat-topped, coal-measure, synclinal mountains, connected with the great mountain plain of Lycoming county to the south-west and south.

Blossburg Mountain, described in the last chapter, crosses the west line and occupies Armenia township. A few high hills in Springfield and Smithfield, of which Mt. Pisgah is the principal, are all that is left of the mountain along the trough which it formerly occupied. No doubt at one time there was a mountain cañon on the Susquehanna in the townships of

Ulster and Sheshequin; and the mountain must have reached the north-east corner of the county and passed on into Broome county, New York.

Towanda Mountain forms the salient feature of the county. Being very broad and flat where it comes out of Lycoming county, it is split lengthwise into two by the deep cañon of Schrœder creek; is cut across tranversely by the gorge of the South Branch creek; and was cut through in early ages by the Susquehanna river. Through Standing Stone, Wyalusing, Tuscarora, Herrick and Pike townships its ancient existence is testified to, and it is in fact continued as a range of high hill-country nearly to Great Bend in Susquehanna county. The right hand branches of Wyalusing creek drain this highland southward; while the left hand branches of Wysox creek, and the head streams of Wappasening and Apolacon creeks drain it northward and westward.

Towanda Mountain is about as high as Blossburg Mountain; the railroad summit at the Barclay Mines being 2,038′; the head of the incline plane, 1,753′; its foot, 1,268′; at Greenwood, where Barclay and Shroeder creeks fall into the Towanda creek, 820′; at Monroeton junction with the railway south to the coal mines of Lycoming county at Bernice, 759′; and at the Towanda junction with the Pennsylvania and New York Canal Division railroad on the banks of the Susquehanna, 741′.

The height of the Mountain above Towanda creek, which flows in a deep narrow valley of erosion at its northern foot, is therefore over 1,200 feet; and the depth of the gorge which splits the mountain is not far from 1,000 feet, the sides being very precipitous and crowned with cliffs of massive conglomerate sometimes one hundred feet thick.

The Susquehanna river at Waverly, in New York, is about 800′ above tide (R. R. grade, 826′.) At Athens, the R. R. grade has fallen to 779′; at Ulster, to 746′; at Towanda, to 741′; at Standingstone, 709; at Rumnerfield, 703′; at Wyalusing, 681′, and at Laceyville, 666′, two miles below the Bradford county line.

The Susquehanna river enters Bradford county at about the same level above tide as that at which Pine creek leaves Tioga

county. Lycoming creek and Towanda creek heading together at 1,200′ above tide flow in opposite directions, the one southwest to Williamsport, (544′,) the other east to Towanda, (741′.) But the former creeks cuts a tremendous cañon transversely through the Allegheny mountain table land of Lycoming county, which in Sullivan county, (next south of Bradford,) attains altitudes above the sea of 2,235′ at Long Pond, and 2,285′ on the turnpike one mile west of Long Pond. This is the highest *recorded* level on the Mehoopany plateau, in Sullivan county.

The terminus of the railroad at the coal mines at Bernice, in Sullivan county, five miles south of the Bradford line, is 1,875′ high. Dushore, at the north foot of the Mehoopany mountain, and in the channel of the north branch of the Loyalsock, which flows along the foot, 1,590′. At New Albany, five miles north of the line, in Bradford county, the railroad grade has fallen to 1,194′; at Wilcox, to 1,120,′ and at Monroeton, on Towanda creek, (after passing through the Towanda mountain,) to 759′.

But the drainage of southern Bradford obeys the same law already noticed as governing that of Tioga county:—all the streams flowing into the Loyalsock head in the middle of the broad valley of Wilcox and New Lancaster, and flow south *toward* and against the foot of the Mehoopany mountain, in Sullivan. The South Branch of Towanda, heading also in the middle of the valley around Wilcox, drains north *towards*, *into* and *through* the Towanda mountain. In this case, also, the same cause operates; the streams follow *down the dip* from the central anticlinal axis of the valley towards the central line of the bottom of each synclinal mountain to the north and to the south of it.

The lowest rocks therefore in Northern Wilmot T., as at Wellsborough and Mansfield, crop out along the centre line of the valley, and are Chemung; while the Catskill rocks form the flanks of the mountains (dipping inward); and the tops of the mountains are made of flat Coal Measures, holding one, two or three of the lowest coals, all the rest having been carried away.

The *echelon* arrangement of the synclinal mountains of Northern Pennsylvania is a remarkable feature of the map already alluded to in the first chapter. Each mountain ends abruptly towards the north-east; but the southern runs on further than the northern.

The Mehoopany or North Mountain of Sullivan and Wyoming counties extends as Elk Mountain into Susquehanna county.

The Towanda Mountain nearly reaches the Susquehanna River in Bradford county.

The Blossburg Mountain stops just after entering the county.

The Tioga Mountain does not reach the east line of Tioga county; having crossed Tioga river.

The Cowanesque Mountain ends still further west, long before reaching the Tioga river.

It is in obedience to the same general law, based upon the geological structure of the country, that the Wyoming (Capoos, Moosick, Lackawanna) Mountain approaches the Delaware river in Wayne; and the Pocono Mountain mass extends (as the Catskill) all the way to the Hudson.

All these mountains are synclinal piles of the same formations: chiefly Catskill and Chemung. As the Tioga, Blossburg and Towanda Mountains have sides of Red Catskill, and crows of White Catskill, from 500′ to 1,000′ feet high, so the Catskill Mountain on the Hudson shows side walls of Red Catskill rocks, supporting peaks of the White Catskill rocks, 4,000 feet high. As these formations *thicken* towards the south-east and east, so do the mountains made of them become higher and higher, and of course longer and longer in the same direction. For both the height and the length of the mass, in each synclinal trough, depend upon its thickness; in other words, upon its ability to resist erosion; or upon the quantity of it which there was originally to be washed away. To the increased thickness must also be added the increased coarseness and solidity of the rocks in the same direction.

In the following chapters detailed descriptions will be given of the Wilmot Valley in southern Bradford; of the Towanda Mountain; of the Towanda creek and Lycoming creek valley;

of the Blossburg Mountain; of the Wellsborough Valley; of the Crooked Creek Mountain; of the Cowanesque valley north of it; and of the Cowanesque Mountain in north-western Tioga county;—and in these descriptions the anticlinals of the valleys and the synclinals of the mountains will be traced and located across both counties consecutively and from east to west in the order given above.

Fig. 2. Sketch of the outcrop of the Seral Conglomerate, No. XII, forming the rim of the Towanda Mountain, in Bradford County.

CHAPTER III.

WILMOT ANTICLINAL.

In the south-east corner of Bradford county we have a valley of about ten miles in width, occcupying Wilmot, Terry and Albany townships, walled in on the south by the Tunkhannock and Loyalsock mountain, and on the north by the Barclay or Towanda mountain.

The valley is watered by the branches of Sugar Run creek, flowing into the Susquehanna river eastward; by the north branch of the Loyalsock flowing west through Sullivan county, and by the head waters of South Towanda creek flowing north through the Towanda mountain. It may be considered as crossing the Susquehanna and stretching out over most of Tuscarora, and over the townships of Wyoming county to the south of it.

The line of the northern wall of Vespertine or Upper Catskill rock (X) commences about the southern corner of Asylum township, passes the South Branch Towanda a mile above S. B. Postoffice, and continues south-west to the county line west of Overton village.

Wilmot Valley continues westward through Sullivan into Lycoming county, being bounded on the south by the North Fork of Loyalsock, flowing in a nearly straight line at the foot of the southern wall of Vespertine rocks (X).

The axis of this wide anticlinal arch of Chemung rocks, sinking each way northward and southward under the overlapping Lower (Red) Catskill, (IX,) at the bases of the mountains, runs along much nearer the southern than the northern side of the valley, the dips being steeper toward the south than toward the north, which is indeed a pretty general rule through Bradford and Tioga counties. The axis, or central

line of the anticlinal, crosses the Susquehanna near where the river enters Wyoming county, and runs on eastward through Auburn township, Susquehanna county. West, it crosses the township line between Wilmot and Albany, about one mile north of the county line, and runs on through the northern townships of Sullivan county into Lycoming county; and is seen crossing Pine creek two or three miles below Ralston.

It will be observed that most of the streams take their rise near the top of the anticlinal axis and flow down the dip north or south. Some, however, as Black Creek, Level Branch and Lick Creek, in Overton township; and others in Sullivan county, cut through the axis, after flowing down from the high summit land of the Towanda or Barclay Mountains. The North Branch of the Loyalsock excavates its channel at the junction of the Chemung rocks (VIII) of the valley with the Red Catskill rocks (IX) of the bounding mountain.

Good exposures are rather scarce in the Wilmot Valley, there being a great abundance of drifted materials over the surface. But it is not difficult to prove that in all of Overton, most of Albany and Terry, and all the northern Wilmot, and southern Tuscarora townships, the dip is to the north-north-west or north-west. Elsewhere, to the south, the dip is the other way, and much steeper.

Over the whole of this area we have one formation, referable to the top of the Chemung (VIII) or to the bottom of the Catskill (IX). The main mass of IX constitutes the base of the Loyalsock and Tunkhannock Mountains, along the Loyalsock Creek, in Sullivan county; and, overlying IX, in the side and at the brow of the mountain, we have in regular succession, ascending, formations X, XI and XII.

The surface rock along the Wilmot anticlinal axis consists, for the most part, of gray upper Chemung sandstone and shaly rock, interstratified with beds of red shale and sandstone belonging to the same formation. In the immediate valleys of the Susquehanna, Sugar Run and Tuscaroras, the prevailing color of the rocks is gray. But from near the mouth of Sugar Run south, there are more or less red rocks, which gradually become more abundant all the way to the north flank of

the Loyalsock and Tunkhannock Mountains, at the south-east corner of Bradford county. The same order is observed in going west through Albany, Terry and Overton townships to the Barclay and Ralston Mountains.

The best exposures of the rocks are along the Susquehanna, on Sugar Run, Tuscarora and Little Tuscarora creeks.

A few flagstone quarries have been opened, one of which has been worked to a considerable extent. It is on the Little Tuscarora, on lands of S. J. Bowers, and it has furnished some good building and flagging stone. The dip is southward, and the beds rise above water level a little farther up the creek.

No ores of any value have been met with.

It is not my purpose to enter into a discussion regarding the age of these and other rocks along the Wilmot axis, as it is not perfeetly clear to my mind whether they should be considered as Chemung or Catskill. The character of the rocks would assign to them a place in the Catskill group; while the fossils make them a part of the Chemung. I once regarded the two groups as easily distinguished formations; but after several years of investigation I am convinced that, if separated at all, it can only be done by means of their physical characters, and not by means of their fossils. For if we make the fossils a guide—and it seems to me the surer guide, because the mechanical sediments must have varied widely in different parts of the sea—we cannot resist the conclusion that they are of one and the same age. In fact, Chemung fossils may be found high up among the *red rocks* of this district, and the red rocks have hitherto been considered Catskill. Indeed, still further to the west, namely, in M'Kean county, (and probably in Potter,) there is some reason for believing that Chemung fossils may be found entirely above the red rocks, among the gray beds of the Vespertine (X).

On the other hand there can be little doubt that these beds are the equivalents of those which, farther to the north-west are known as Upper Chemung, differing from them only in color and texture. We may say that this phenomenon is apparent over a large area; what is Lower Catskill, in any place towards the south-east, becomes upper Chemung on going not many miles towards the south-west. This helps to explain

why there are no red rocks west of the Susquehanna along the crown of the more northern anticlinals.

A description of beds of the same age farther to the north-west, nearer to the Chemung river, where the Chemung types were first determined, would hardly apply to these strata. The physical characters of the same rocks in the two districts are widely different. Here there is less calcareous rock, and the texture is coarser; there is more sandstone and less shale; and the shale which is there greenish-gray, is here often of a red color, and cannot be distinguished from the red shale beds of the true Catskill Formation. The sandstones were formed in a less tranquil sea, with contrary currents, of which frequent evidence is afforded by the oblique lamination.

The difference is also strongly marked by the fossils themselves. Of invertebrates in this Wilmot district there are both fewer species and fewer individuals. It is a signal fact that we fail to find those countless myriads of remains of shells which peopled the Chemung sea in the other region only thirty or forty miles to the north and north-west. Not that fossils of this character are entirely wanting. We occasionally find them in thin, gray, calcareous bands, which occur at intervals in the series; and they are mostly of the same species as those found so much more abundantly at the same geological horizon further north. The most prominent of them are *Grammysia elliptica*, *Rhynchonella contracta*, *Streptorhynchus pandora*, *Athyris angelica*, and two or three species of *Productus*.

A locality on Sugar run may be mentioned where these species can be collected from a gray rock, exposed on the run at a point about three-fourths of a mile from the Susquehanna river.

The same species were obtained from a stratum of calcareous rock outcropping along the Susquehanna, opposite to Browntown, below the mouth of Sugar Run.

They were got also from masses of calcareous rock lying loose on the west side of the river at Kinney's Ferry.

The best locality, perhaps, for studying the conditions under which these fossils occur, and the character of the beds containing them, is one near the south-east corner of Tuscarora township, (but probably within the limits of Wyoming and

Susquehanna counties,) along "the mountain road," ascending from and a little east of Skinner's Eddy. We have here:—first, at the foot of the hill, about two hundred feet (200′) concealed, the surface covered with red and gray stones;—second, two hundred and eight feet (208′) of alternating red and gray beds, one thin band containing fragments of fish remains (*Holoptychius ?*):—third, one hundred and twenty-two feet (122′) of gray shale and sandstone, containing broken fragments of plants and fossil shells of well known Chemung species, including among others, *Rhynchonella contracta* and *Spirifer mesacostalis;*—fourth, five or ten feet (5′–10′) of reddish shale or sandstone in thin bands;—fifth, five or ten feet (5′–10′) of gray sandstone, at the top of the hill. Many of the foregoing beds are diagonally laminated. The section reads thus:—

Skinners's Eddy Section, Bradford Co.

5. Gray Sandstone, top of hill	5′ to 10′
4. Reddish shale, thin sandstones	5′ to 10′
3. Gray shale and sandstone; broken *plants* and Chemung *shells*	122
2. Red and gray alternations, with one thin *fish bed*,	208′
1. Red and gray surface debris down to the foot of the hill	200′
Total height of the section	550′

But fossils are not abundant even here; while in Albany, Terry and Overton townships we saw none whatever. Their horizon probably keeps farther to the south, through Sullivan county, near the North Branch of the Loyalsock.

While there is a paucity of marine fossils, (shells,) compared with more northern localities, the relics of vegetation (plants) are a hundred fold more numerous. What is lacking in animal remains is made up in the abundance of the fossil flora. Carbonized stems of reed-like plants are very common, and in some places beds of one to two feet or more are largely composed of them.

The greater part of the impressions noticed appear to be those of aquatic plants, which grew in shallow water along the margin of bays and rivers; with fragments of land vegetation, (ferns, etc.,) apparently, in many instances, broken and ground up by waves and streams, before being floated off and

deposited at the bottom of the sea. This ground-up, decayed wood, embedded in sand, is usually carbonized or converted into coaly matter, and appears thus in the exposures.

NOTE.—In the Final Report of 1858, Vol. I, page 307, 308, the Wilmot anticlinal is described as crossing Lycoming creek one mile above the mouth of Pleasant Stream, and "ranging thence *in an almost perfectly straight course* through the middle of the valley to the North Branch of the Susquehanna, which it crosses *near Wyalusing Falls.*" These falls are a number of miles below the mouth of Wyalusing creek, and are not far above the point of Wyoming county. So that the description of the locality at which the axis crosses the river is sufficiently exact. But it is contrary to the law of these anticlinal and synclinal waves, that they should run straight; and it is rare to find one that does. The representation of the space between the Towanda mountain and the Mahoopeny mountain, upon the Geological map of 1858, is incorrect in being too symmetrically straight; and in not showing the northern belt of red (Catskill) rocks to be much wider than the southern belt.

CHAPTER IV.

TOWANDA MOUNTAIN SYNCLINAL.

In Bradford county this is known as Towanda mountain; in Lycoming county, as Laurel Hill. The Indian name is said to signify the "Long Smoky Mountains."

The north flank of this long range of high land borders Tioga county on the south from Liberty township, Tioga county south of Nauvoo, and east of Zimmerman's creek; at first bending southward to the county line; keeping just within the edge of Lycoming county as far as to the south-west corner of Bradford county; thence along the south side of Towanda creek to the mouth of the Shræder branch, three-quarters of a mile south of Greenwood. The south branch of Towanda creek breaks out of it about a mile and a half south of Monroeton, cutting off the east end of the range, which stands as an isolated mountain, with its point near where Asylum, Terry and Albany township lines meet. The Red Catskill rocks, forming the base of the mountain, continue on towards the river, and come to a point within a mile of Terrytown.

The south flank of the mountain has been described in the last chapter. The gorge of South Branch Towanda creek commences about one mile above South Branch post office. Overton is situated near the foot of the mountain, which may be said to leave Bradford and enter Sullivan about five miles west of Overton, and is then seen as a high wall running on south-west towards Lycoming county.

The axis of the synclinal is seen on Pine creek, near the mouth of Roaring Brook; sweeps round, along the north side of the Shræder branch, through the Barclay coal mines, and crosses the Susquehanna between Terrytown and Wyalusing. East of the river, it curves up through Wyalusing to the north-east corner of Tuscarora, and passes on to Montrose. The sides of

the mountain mass are bold and regular, and its height nearly uniform, giving a sky outline which, at a little distance, appears to be for miles nearly horizontal. The interior of the mountain is split lengthwise by the long deep gorges of Shræder's creek, and a shorter trench cut by a branch of the same. Numerous ravines descending into these main streams break up the interior mass into a system of sharp, steep-sided ridges, pointing in towards the synclinal axis.

The cross cañon of South Branch cuts the mountain crosswise to its base, and into this descend two side ravines. The north wall is occasionally scored by short runs descending to Towanda creek and Pine creek, and in Sullivan county, the south wall is broken by the head waters of the Elkland branch of the Loyalsock, on one of which are Lincoln Falls.

Numerous small lakes or ponds, like Elk lake in Sullivan county, rest in hollows of the highest table land. Three of these in Bradford county are known as Sun Fish Pond, Mud Pond and Holcomb Pond, drained by streams of the same name. Others once existed at the same remarkable elevation, but have become filled up and converted into marshes, meadows or laurel swamps—as Cranberry Marsh, Pine Swamp, etc.

The geological structure of this mountain basin is very simple and easily understood. The base on either side is composed of the red shales and sandstones of the Lower Catskill Group, or Formation IX, reaching nearly half way up the face of the mountain. These rocks crop out boldly to the north along Roaring Branch and Lycoming creeks, at the south-east corner of Tioga county, and along Towanda creek, between Monroeton and East Canton, in Bradford county. The same rocks spread out on a gentler dip farther from the base of the mountain into the Wilmot anticlinal valley to the south.

Above the red rocks, and reaching nearly or quite to the top of the rim of the basin on either side, is the continuous outcrop of the Vespertine (X) or Upper (White) Catskill formation, composed principally of gray sandstone.

These are capped by the Umbral (XI,) in which red shales predominate, and being softer than the Vespertine, form gentle slopes above the steeps below.

The next overlying Millstone Grit, or Conglomerate (XII,)

makes a bold escarpment or sky line. In many places the underlying shales have decomposed and undermined the Conglomerate, letting down large masses of it in detached blocks, which often make a prominent feature in the landscape.

The Coal Measures (XIII) have been eroded from a large part of the upper surface of the mountain; the two principal areas remaining being, one at Ralston in Lycoming county, and one at Barclay in Bradford county.

On the south bank of the basin the dip is gentle to the north north-west. On the north flank it is sharp to the south south-east; as may be noticed in many fine exposures along Roaring Branch, Lycoming and Towanda creeks, where dips of 25°, 35° and even 45°, may be measured. The steepness of dip increases coming from Tioga into Bradford county, and then diminishes as we approach Towanda, where it is reduced to 10°. But the steep dips are confined to the base of the mountain. On the plateau, around the edges of the coal measures the dip is exceedingly gentle, becoming perfectly horizontal along the centre line of the mountain. The dips observable along the Susquehanna, around the end of the mountain, are very gentle and slightly westward. And in the townships east of the river the synclinal is very shallow and the dips gentle. It is this which has brought the mountain to an end in this direction, allowing of its being entirely washed away in former times; for it once extended far beyond Montrose, and probably across the Delaware river.

The Catskill rocks of the Barclay and Ralston basin consist of red shale and red sandstone, bluish shale and gray sandstone. Red is the predominating color, both of the rock and of the soil resulting from its disintegration. The shales are mostly clay sometimes mixed with very fine sand. The sandstones, as a rule, are coarser than those of the Chemung group, and are characteristically false-bedded. They are also often filled with flakes of mica.

These strata constitute the base of the mountain on the south side, and extend about half way up the side. From the foot of the mountains they spread out over the hills of the Wilmot anticlinal valley. On the north side the belt is narrower, not

more than half a mile wide, and extends about half way up the side.

The Catskill rocks cap the hills in the district colored red on the map on both sides of the river east and west of Terrytown.

In the gorges of the South Branch and Shraeder, the red Catskill rocks are at water level.

In Canton county they ride over the Towanda anticlinal in a continuous sheet, uniting the bases of the two mountains, the Towanda and the Blossburg. This is also the case in Liberty township, Tioga county; and westward from the Block House settlement.

Exposures are numerous, but not of any great vertical extent. The best are along Roaring Branch and Lycoming creek, at the line between Tioga and Lycoming counties; also along Towanda creek and its branches.

The following section is seen on the north side of Towanda creek, near a bridge, one mile above Monroeton; numbering from above downwards:—

	Feet.
1. Gray shale and shaly rock, and calcareous rock with fossil shells	40
2. Red shale and sandstone, with fragments of fish remains (*Holoptychius?*)	30
3. Gray shale and sandstone, and calcareous rock with fossil shells	40
	110

At the Monroeton bridge there are seen alternations of red and gray sandstone, the horizon of which appears to be lower than the preceding section. I am unable to say whether they should be regarded as Chemung or Catskill. The dip at both places is sharp to the south.

Above Wyalusing, and across the river from Terrytown, there is an interesting and fine exposure of about a mile and a half in length along the railroad. The bottom of the Towanda Mountain synclinal crosses the river at or near this place; for at the north end of the cliff the rise is considerable towards the north. A bed of red shale thirty or forty feet thick, is here seen to be overlaid by a thick mass of gray rocks, with fossil shells; and over these again are other beds of red shale and sandstone, which are exposed in the main road on

top of the hill. These in their turn are overlaid between J. R. Taylor's and E. Chamberlain's, by other beds of gray shale and sandstone, containing fossil shells, plant stems and fish remains. I am again at a loss whether to look upon these beds as Chemung or Catskill.

A short distance east of the dépôt at Wyalusing the following section is exposed in a quarry, reading downwards:

	Feet.
1. Gray sandstone, with two or three thin calcareous bands containing plant-stems and fragments of fish remains	55
2. Bluish shale and calcareous rock, with fragments of fish remains	4
3. Gray and bluish sandy shale	4
4. Red shale	8
5. Bluish-gray sandstone	6
	77

Along the main road on the east side of the Wyalusing, about a mile and a quarter above Wyalusing village, and again about a mile and a quarter farther up the stream, the fields are strewn with large detached masses of *limestone*, resembling in every respect that worked by Kline, in Burlington township, to be mentioned in the next chapter.

Two miles up Wyalusing creek, in the west bank and near the House of A. Culver, there is a good exposure of bluish shale and calcareous rock, containing shells and plant stems, and having a considerable dip to the *south south-west.*

As regards all the foregoing localities, it remains to be determined whether they be Chemung or Catskill. I have not found any fossil shells at a much higher level in this basin. These strata pass by easy gradations up into a mass of red beds in the side of the mountain, in which, so far, I have observed no fossil shells. The upper strata may therefore be considered non-fossiliferous, except as regards plants and remains of fish.

These same upper beds cap the hills through the central and southern portion of Wyalusing, the northern part of Tuscarora, and the south-east corner of Pike, and spread eastward through Susquehanna county.

They were met with in considerable force where the road from Browntown north descends into the Wyalusing valley;

and again on top of the hill, about a mile further north-east, near the house of P. Miller. But the best locality, perhaps, is in the north-east corner of Tusearora township, where the road goes over a hill, between the houses of M. Bennett and W. Bradshaw.

The aggregate thickness of the Catskill rocks in the Towanda mountain basin, *not including the beds at the bottom which contain fossil shells*, is probably not less than eight hundred feet.

In all this mass I have seen no indications of any minerals of value.

CHAPTER V.

TOWANDA ANTICLINAL.

This axis has been described already as passing through southern Union township, Tioga county, and crossing the Northern Central R. R. about half a mile north of Grover P. O. Canton T. It keeps on past E. Canton, by the north-west corner of Franklin, and south-west corner of Burlington, to the mouth of Towanda creek. It is seen in the bend of the Susquehanna at the line between Wysox and Standing Stone, and is then indistinctly traceable through Herrick and Pike into Susquehanna county.

In Union T. Tioga Co. Sugar Mill run, E. and W. Mill creeks drain the south slope of Blossburg Mountain across it into Lycoming creek. Other brooks in Liberty T. descend from it into Roaring brook. Block House run waters cut across it also about Veilstown and Henslertown. Zimmerman's creek flows west past Nauvoo and then cuts through it southward into Pine creek.

On the eastern side of Tioga county all the branches of Wyalusing creek flow south from it into the main stream, and the dip of the rocks on these waters is always, therefore, down stream.

But in Asylum township, Ellis's, Bennett's and Durell's small creeks flow from the mountain towards the anticlinal, and the dip of the rocks on these waters is consequently up stream.

The surface features of the region through which this anticlinal goes are those of low, rounded hills, intersected by small streams. In Liberty township, Tioga county, the land is high and gently rolling; further east the streams cut deeper and the surface is therefore more hilly, but always adapted for agriculture.

The surface rock over most of this anticlinal valley consists of gray shales and sandstones, belonging to the Chemung Group, (the upper part of Formation VIII). Towards the west, in Liberty township, Tioga county, these rocks slowly sink from view beneath a surface of the red Catskill beds of IX. Farther east these last make a red margin to the valley, both on the north and on the south of the anticlinal, but broader on the north side of it than on the south side, which latter belt forms the foot slope of the Towanda Mountain range, south of the creek.

East of the Susquehanna, in Herrick, Pike, and other townships adjoining, there are such quantities of nearly horizontal red rock as to leave it in doubt whether the strata should be considered as Chemung or Catskill, though they must be in the same horizon as beds which are gray farther west, and which we know there as Chemung.

Along the south side of the valley the dip is sharp to the south-east. In many places along Roaring Branch, Lycoming, (above Roaring run,) and Towanda creeks, it ranges from 25° to 45°, and appears to be sharpest just at the junction of Formations VIII and IX, a fact which may be observed almost anywhere along the above named streams. East of the Susquehanna river the south dip is still steeper than the north, but quite gentle compared with the dips observable towards the upper end of Towanda creek.

The gentle north dip may be seen at Cedar Ledge, two miles south of Canton, as well as along the railroad near the village; also, at Troy, and thence down Sugar Creek to its mouth, near Towanda. But the finest exposures of the north dip are on the Susquehanna, opposite and a little above Towanda, and at the Red Rocks below Wysauking.

The geology may be easily studied in fine exposures along Roaring run and Towanda creek, and many of the cliffs are so high and extensive as to be conspicuous objects in the landscape.

The upper rocks of VIII are finely displayed, for example: about a mile west of Green's saw-mill, Union T. Tioga county. And all the way along the Lycoming valley, from Roaring Branch to Corner Stone, are many outcrops of the upper beds

of VIII and the lower beds of IX, both on the common road and on the railroad.

At Cedar Ledge, two miles south of Canton, and in the railroad cut, between that point and the village, and again about two miles north of Granville Summit, following the line of the railroad, are good exposures: the first two in the lower beds of the IX, and the last two in beds about the top of VIII.

Two specially large and interesting exposures on Towanda creek may be mentioned. One at Leroy, on Gulf Brook; the other at "the Narrows," a mile below Franklindale.

Two extensive cliffs have been laid bare by the wash of the Susquehanna; opposite Towanda; and below Wysauking, where the river turns sharply to the south at "the Narrows." In this most interesting and instructive locality is seen a fault to be described further on.

The Chemung rocks seen along the Towanda anticlinal, west of the Susquehanna river, consist of gray shale and sandstone, sometimes of a bluish, greenish or olive tint, with certain beds which are more or less charged with lime.

East of the Susquehanna these beds are gradually replaced, to a certain extent, by red shale and sandstone, of a character similar to the strata described in the preceding chapter, and which are in general of a coarser texture, and more frequently false-bedded, while fossil shells are not so numerous nor so well preserved. Going in that direction we are evidently moving towards some old shore line, and towards the mouths of large rivers which drained lands once lying perhaps far away to the eastward.

It has been already said of the Wilmot district, how difficult it is to tell whether these red strata should be considered as Chemung (VIII) or Catskill (IX).

In fact it seems as if there will always be a difficulty in the way of separating the Chemung from the Catskill. For we cannot avoid the conclusion that beds which are gray, greenish, bluish and olive-tinted in the Upper Chemung, *filled* with *invertebrate* fossils, and from three to five hundred feet, or even more, in thickness, over the portion of my district lying immediately west and north-west of the Susquehanna, are, as before

stated, replaced to a certain extent with beds of red shale and sandstone on crossing that river into the eastern townships of Bradford county. And the same change seems to take place on crossing the Barclay and Ralston (Towanda Mountain) basin to the north. Although the change, or transition, is everywhere perceptible throughout my district, it is most marked in the vicinity of the Susquehanna river and along the Barclay and Ralston Mountains.

As to the *calcareous beds* of these transition strata (VIII–IX) they are to be found both east and west of the river, and both north and south of the Towanda Mountain trough. But they help to show the transitional character of the formation, inasmuch as they thicken north-westward in the gray region, and thin steadily southwards in the red region. Moreover, they contain a greater abundance of fossils going north-west, and fewer shells going south-east.

It has been already stated, however, that fossils of the same undoubted Chemung species may be found high up in what is known as the Catskill Group, especially in Tioga county, and in M'Kean and perhaps in Potter. They may be found still higher, in what is known as the Vespertine Group, (X). Hence it is apparent that the Chemung, Catskill and Vespertine are of the same age, if fossils be taken as a correct standard of judgment. But these groups certainly vary in their physical characters at almost any given locality, and on this account, if no other, it would seem to be desirable to retain the names by which they have been so long known.*

With this general description and explanation we may say that the *Chemung rocks* (to retain the name) occupy a belt about three miles wide in the south-east corner of Tioga county, narrowing westward to a point on the Lycoming county line,

*The Catskill and Chemung are names well chosen. This is not quite the case with the Vespertine, unless we adopt the whole nomenclature of Rogers. As these rocks constitute the mass of the Allegheny mountains, I think the name of *Allegheny Group* would be more appropriate.

[In this I do not agree with Mr. Sherwood, for the reason that VIII, IX and X, are so strongly marked as different formations all through Middle Pennsylvania, and especially around the Anthracite Coal Basins, where they were first studied and separately numbered in 1835 and 1836 by Prof. Rogers and his assistants on the first Geological Survey. J. P. L.]

about two miles south-east of Henslertown. For the borders of this triangular belt the reader is referred to the map.

Chemung rocks cover, in Bradford county, the central portion of Canton T., except south of Canton village, where it is confined to the valley of Towanda Creek, owing to the piling up of the red rocks of IX, and their arching over the anticlinal.

North-east of Canton, the Chemung belt rapidly widens, so as to occupy all Le Roy township, north of Towanda Creek, the whole of Granville, the south-east part of Troy, the larger part of West Burlington, the whole of Burlington, that part of Franklin lying north of Towanda Creek, the north part of Monroe, the whole of Towanda and North Towanda, with such parts of Asylum, Wyalusing, Standing Stone and Wysox as border on the Susquehanna river. The rest of these last named townships make up the doubtful region of Chemung-Catskill transitional beds, with Herrick and Pike.

In Tioga county, perhaps the best exposure of Chemung rocks takes place on a small stream coming into Roaring Branch from the north, about a mile above Green's saw mill; the dip being at a high angle to the south south-east.

Fossils were not met with in any numbers.

Iron ore was found at three different localities in Union township, the most important of which is on the main road, about one mile south-east of Ogden's Corners. Here we found the following beds, the thickness of each being estimated, except the beds of iron ore, which were measured:

Ogden's Corners Section.

1. Gray shaly rock, thickness unknown	?	
2. Iron ore	4′	
3. Gray shaly rock	10′	
4. Iron ore	1′	5″
5. Gray or reddish rock.	1′	8″
6. Iron ore	0′	8″
7. Gray rock, somewhat concretionary	12′	
8. Iron ore	1′	
9. Gray shaly rock	40′	
10. Red shale	3′	
11. Gray shaly rock	20′	
	93′	9″

No excavations have been made into these beds except those made by us. They are on lands of Mr. Hermon and Mr. Meetem. The dip is north-westerly.

A partial analysis by Mr. A. S. M'Creath, at Harrisburg, gave the following results:

Ore from the top band, marked No. 2.

Iron	39.300
Sulphur	.027
Phosphorus	.184
Insoluble residue	34.400

Ore from the second band, marked No. 4.

Iron	31.300
Sulphur	.018
Phosphorus	.229
Insoluble residue	44.420

Ore from the third band, marked No. 6.

Iron	37.000
Sulphur	trace.
Phosphorus	.241
Insoluble residue	36.370

Ore from the bottom band, marked No. 8.

(Analysed by David M'Creath.)

Iron	28.900
Sulphur	.015
Phosphorus	.298
Insoluble residue	44.980

Iron ore (Chemung) crosses the main road, in Union T. Tioga county, a few rods north of Roaring Branch post office. The bed is less than a foot thick; too thin to be of much value, although it has been worked to some extent.

An analysis by Mr. A. S. M'Creath shows its character, as follows:—

Iron	28.850
Sulphur	.018
Phosphorus	.233
Insoluble residue	50.470

The same bed has been mined a little at a place one-third of a mile east of J. Pratt's, near the main road, although here only eight inches thick.

It will be seen from the following analysis by Mr. M'Creath that the percentage of iron in it is quite small:

Iron	18.500
Sulphur	.033
Phosphorus	.191
Lime	———
Magnesia	———
Insoluble residue	62.360

Iron ore, in Canton township, Bradford county, was found at three or four localities along Towanda creek, and from two to three miles above Canton village.

1. In the side hill, east of Ichabod Sellard's, we found a bed measuring eight feet in thickness, but of a very poor quality at least towards the top. The dip is to the north-west, and we traced the bed about a mile to the north, along the side of the hill, to where the dip carries it beneath the creek.

A partial analysis by Mr. M'Creath shows that the quantity of iron in the bed is too small to be of any value.

Iron	14.60
Sulphur	——
Phosphorus	——
Insoluble residue	65.52

2. The same bed dipping similarly to the north-west has been opened with better results on the same farm, but on the west side of the creek. Six or seven hundred tons of this ore has been taken to a furnace somewhere in Lycoming county. The bed is separated by a parting of rock, as follows:

Top, gray shaly rock, with fossil shells.	
Iron ore	2′ 6
Rock	1′ 6″
Iron ore	1′ 6″

A partial analysis by Mr. M'Creath gave the following results:

Iron	32.200
Sulphur	.059
Phosphorus	.311
Lime	———
Magnesia	———
Insoluble residue	40.640

3. The same bed, dipping north-west, has been mined about three-fourths of a mile north of the last locality, on land of Enoch Sellard, in the bank of a creek, and five or six hundred tons taken to the same furnace. It is here three and one-half feet thick (3′ 6″).

The following is a partial analysis by Mr. M'Creath:—

Iron	28.500
Sulphur	.039
Phosphorus	.294
Insoluble residue	45.110

At the two last named localities the ore contains shells and *fish remains.* The latter are mostly in a fragmentary condition, but indicate fishes of large size, and probably of new or undescribed species.

4. In the main road south-east of Canton, near the house of B. D. Barnes, and west of Mud Lake, we found a bed of iron ore, perhaps two feet thick, the quality of which will be seen by the following analysis made by Mr. M'Creath:—

Iron	28.400
Sulphur	.014
Phosphorus	.258
Lime	———
Magnesia	———
Insoluble residue	45.310

5. In Troy township, in the main road below East Troy, between the houses of M. Jones and A. Parke, we found a bed of iron ore about one foot thick, and of rather poor quality, as appears from the following analysis by Mr. M'Creath:—

Iron	24.700
Sulphur	.016
Phosphorus	.248
Lime	———
Magnesia	———
Insoluble residue	52.440

6. In LeRoy township, about a mile and a half west of Le Roy, in the main road, near the house of J. Wileox, we found a bed of iron ore which appeared to be three or four feet thick and of very good quality; see the following partial analysis by Mr. M'Creath:—

Iron	29.500
Sulphur	trace.
Phosphorus	.204
Lime	———
Magnesia	———
Insoluble residue	49.270

7. The same bed is exposed at LeRoy village, in Gulf Brook, where it is nearly four feet thiek and of good quality.

A partial analysis of the ore by Mr. M'Creath resulted as follows, though it ean hardly be a fair test, for the average per centage of iron must be greater:

Iron	20.700
Sulphur	trace.
Phosphorus	.185
Lime	8.710
Magnesia	1.300
Insoluble residue	46.655

At this place, and about one hundred feet higher up, there is another bed containing a small percentage of iron, but a much larger quantity of lime. The water percolating through this bed, and impregnated with lime, has made small deposits of calcareous tufa wherever it reaches the surface.

There is a very fine exposure of rocks at this spot. The dip is very strong to the south south-east. A short distance below LeRoy, in the main road, the strata seem to be slightly folded back upon themselves.

Fossils in Franklin Township.—A mile below Franklindale, at the narrows, there is a fine display of Upper Chemung and Lower Catskill rocks, dipping rapidly to the south. The Chemung beds are gray, and contain fossils, especially *Grammysia elliptica*, which occur in great number, in fact more than we ever saw at any other locality. They appear to have existed here in schools or shoals, which seems to have been the habit of lamellibranchiates in general, so far as my observation goes. They lived in communities.

Many of the specimens found at this locality are distorted or pressed out of shape by the weight of or movements in the rocks. Recent excavations by Mr. Horace Willey, to whom the Survey is indebted for the gift of specimens, have revealed such numbers of these fossils as to excite the curiosity of the inhabitants, some of whom requested me, when visiting the spot, to explain through the local papers the manner in which they had become embedded in the strata in which they are found. This I attempted to do through the columns of the *Towanda Reporter*.

The Burlington Limestone.—About a mile east of Burlington, on the farms of W. B. Kline, J. Morley, and C. E. Campbell, there is a bed of rock the most remarkable I have seen in my whole district. It is a calcareous stratum forty feet in thickness—the same throughout. It is a nearly solid mass of sea-shells, which may be reckoned at millions. It must have

required a very long period of time for their accumulation. In the whole forty feet exposed—and this does not seem to be its whole thickness—there is no parting of shale or other rock. The percentage of lime, which is considerable, appears to be about the same in all parts of the bed. Mr. Kline has recently commenced burning this limestone, selling the lime at the kiln for fifteen cents per bushel. It makes a gray, but very strong lime, well adapted to agricultural purposes. The facilities for quarrying the stone cannot be excelled.

This is the thickest stratum of limestone I have ever seen in the Chemung Group, and must prove of value, as it occurs in a region destitute of lime, and where the farms would be greatly benefited by an application of this mineral manure. The bed has a considerable lateral extension through the region, for I have found it at several points east of the Susquehanna river.

Mr. M'Creath's analysis of this limestone shows the following ingredients:

Sesqui-oxide of iron	4.428
Alumina	2.613
Lime	41.048
Magnesia	1.135
Sulphuric acid	.167
Phosphoric acid	.279
Carbonic acid	33.240
Insoluble residue	18.010
	100.920

Sandstone.—In the north-west corner of Towanda and the south-west corner of Ulster townships there is a considerable quantity of sandstone of a whitish color strewn over the surface.

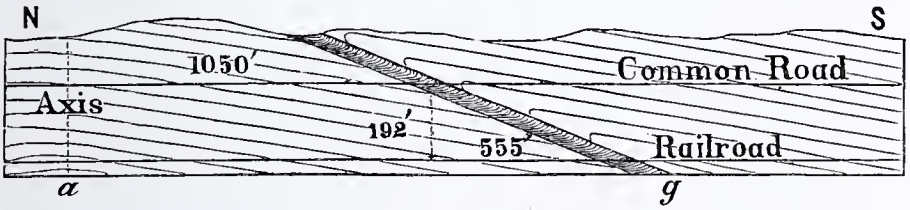
In Asylum township, at Asylum Centre, along Bennett's creek, gray rocks are seen dipping to the south.

Towanda Sandstone with Fossil Plants.—In Wysox township, opposite and a little above Towanda, there is an extensive outcrop, perhaps three hundred feet in thickness, having a considerable dip to the north, and containing carbonized stems of reed-like plants, similar to those mentioned in the preceding chapter. The color is gray, except towards the top of the section, where there are one or two beds of red shale, one of which

is ten feet thick. The plant remains are so numerous that the coaly matter into which they have been converted has given rise to the belief that a workable bed of coal might be found here. It is needless to say that all such hopes are groundless, as there is no probability of finding anything more by excavating than can be seen at the surface. Some good building stone are obtained at this place.

The Wysox Fault.—Where the line between Wysox and Standing Stone townships touches the river, and the Susquehanna strikes the cliffs and bends sharply round to the south, there occurs, on a large scale, a very interesting exposure of gray and bluish shale and sandstone, which may be studied both below along the railroad, and two hundred feet higher up the cliff on the county road. The center line of the Towanda anticlinal crosses the river at the northern end of this cliff,

Fig. 3. *Fault in Chemung Rocks, Bradford Co., Pa.*



while near the middle of the exposure or 1,050 feet further south, along the main road, there is a curious fold, or fault, represented in *Fig.* 3, in which *a* is the Towanda anticlinal axis; *g* the fold or fault.

This disturbance does not pass directly downwards through the strata. For, along the railroad, which is engineered at the foot of the cliffs 192 feet lower down, the disturbance is 555 feet further south. The rocks on the two sides of the fault do not correspond, though they all belong to the Chemung. The break itself occupies a space of from fifteen to thirty feet, in which the rocks are contorted and ground up, while the edges of the strata on either side are polished smooth as glass and brushed into a sloping position as if by a sliding movement.

Fossil Forest.—At the above locality, along the main road, there are carbonized stems of plants; and one layer, of from one to two feet, is filled with what seems to have been roots, which must have grown where they occur, for they cut the strata

transversely. They exist as casts, the roots themselves having disappeared and the cavities become filled by infiltration.

Rummerfield Creek Fault.—In Standing Stone township, on Rummerfield creek, about a mile and a half above its mouth, and between two saw mills, there are indications of a disturbance, which may be the same as the one mentioned above, or it may be another. At Coe's mill gray and reddish shale and sandstone have a rapid northern dip, while at Dixon's mill, a few rods above, the dip is gently to the south.

Flagstone Quarry.—At the forks of Rummerfield creek, in the same township, and on land of W. M. Sherwood, there is a valuable flagstone quarry, which has been worked to a considerable extent. The beds are overlaid by reddish sandstone and red shale, while the dip is to the north.

On a hill eastward from the mouth of Rummerfield creek, the following beds are exposed:

On top: Gray sandstone, obliquely laminated	15
Gray shale, with calcareous bands containing fossil shells	15′
Gray sandstone, obliquely laminated	30′
Red shale	3′
Gray sandstone, obliquely laminated	12′
	75′

Carbonized Plants.—In Wyalusing township, at Lime Hill P. O., in the north-west part of the township, gray shales and sandstones are exposed in the road, with a southerly dip. Some of the layers are filled with carbonized stems of plants. Pieces of limestone, or calcareous rock, are strewn over the surface; evidently the same as Kline's limestone in Burlington township, previously mentioned.

In Herrick township, in the south-east corner, near the house of H. Stethers, there is a peculiar brownish, ochery soil in the road, arising, apparently, from the decomposition of a sandstone layer.

Burlington Limestone.—About a mile and a quarter north of west from Herrick postoffice, above the road and near the house of B. Carr, there are fifteen feet of reddish sandstone and bands of limy rock, dipping north This also is a representative of Kline's limestone, before mentioned. It contains fossil shells.

The same bed is exposed again about a mile south of west from Herrick, at the forks of the road. Here it contains more lime.

Burlington Limestone.—In Pike township, at a school house, about four miles west of south from LeRoysville, there is an outcrop of limestone, which is probable the same as Kline's. Here, below the limestone, there is a bed of red shale, dipping north, ten feet or more in thickness, which may be seen near the forks of the road.

The same limestone is again exposed about two miles below LeRoysville, in the bank above the road near its forks, and not far from Dr. Cogswell's house. It appears to have considerable thickness, and may prove of value.

NOTES—The soil of the Towanda Creek Valley is derived from No. IX, which rises 300 feet up the mountain side, and the bench above it is a marked feature.

The Chemung rocks (VIII) rises from the water's edge, and usually compose the mass of the hills north of the creek. When a hill is high enough to hold a cap of Catskill (IX) the fact is shown by a steep and regular bench near the summit.

The Catskill is 1,000′ on the Loyalsock, and only about 400′ thick in the Armenia (Blossburg) mountain, near Canton Corners.

The anticlinal axis may be seen well on the creek two miles south of Canton Corners, along the north side of which the rocks dip gently northward. On the opposite side of the creek, 400′ to the east, rises a bold hill, with fine cliffs of red and greenish sandstone and slate (IX), dipping southwards at the south end of the exposure.

Here the two beds of ore were exposed as early as 1841, and gave the following section:—

1.	Chemung shales; Calcareous, almost a limestone; full of fossils.....	10′
2.	Upper bed of iron ore, red, fossiliferous.....	2′
3.	Shale and slate, greenish, flaggy, fossiliferous.....	8′
4.	Lower bed of iron ore; a red, fossiliferous, ferriferous sandstone, a good deal like the fossil block-ore of the Clinton (V), on Montour's Ridge at Danville.....	3′

The Chemung limestones were determined by the first survey as lying, the upper bed within 50′ of the top of the Chemung

grey rocks (VIII), and the other 150′ lower down, *i. e.* 200′ below the bottom of IX The lower bed was always the thickest, being 10′ to 15′ thick on the Susquehanna below Towanda. It was traced for miles along the northern dips of the Wilmot anticlinal. The iron ore beds are connected with this lower mass of limestone, and may be expected at about 200′ below the bottom of the red rocks of IX. But there are red shales *with* the ore beds.

Both ore beds contain *Encrini*, *Atrypa punctata*, *Delthyris mucronata*, *Cypricoides*, and several other fossils.—[F. R. 1858.]

CHAPTER VI.

BLOSSBURG MOUNTAIN SYNCLINAL.

The Blossburg Mountain Basin lies between the Towanda anticlinal valley on the south, and the Mansfield and Wellsboro' anticlinal valley on the north. The mountain mass is called by people in Bradford county the *Armenia Mountains.* In Liberty township, Tioga county, it has received the name of *Briar Hill.*

The north flank of this range enters Tioga county at its south-west corner; crosses Cedar creek from one to two miles below the lumber camps of Mr. S. X. Billings, in Elk township; Pine creek, towards the north-west corner of Morris township; Stony Fork, about two miles south of Stony Fork P. O.; and Wilson creek, about half a mile below its forks, in Delmar township; the Corning, Cowanesque and Antrim railroad, near the north line of Duncan township; entering Covington township about a mile south of Cherry Flats. It crosses the Tioga river about two miles above Covington village, entering Sullivan township at its south-west corner. It enters Bradford county in the south-west corner of Columbia township, keeping very nearly on the line between Armenia and Columbia. It then turns south, and keeps along the line between Armenia and Troy, and so follows round the Armenia township line back into Tioga county, as the south flank of the mountain, through Union, Liberty and Morris, west of Nauvoo and north of Zimmerman's creek. This line passes about a mile north of Ogden's Corners in Union township.

The mountainous region thus enclosed embraces the south side of Elk, nearly all of Morris and Duncan, the north side of Liberty and Union, and the south side of Covington and Sullivan, all of Bloss, Hamilton and Ward townships, Tioga

county; and in Bradford county all of Armenia, making a precipitous wall at the eastern line of this township.

Beyond the end of the mountain to the north-east, in Bradford county, are a few elevated points, one of which lies on the line between Springfield and Troy townships, east of the Northern Central railroad.

The bold knob, known as Mount Pisgah, lying principally in the south part of Springfield, but touching the corner of Troy and West Burlington townships, is one of the most conspicuous topographical features in Northern Pennsylvania. This famous landmark is separated from the Armenia or Blossburg mountains, with which it must once have been connected, by a broad valley of erosion, and is rendered prominent by its altitude as well as its isolation.

The centre line, or synclinal axis, comes up from the southwest out of Clinton and Potter counties, south of Kettle creek, and enters Tioga county near the south-east corner of Elk, from whence it passes through the heart of Morris, crossing Pine creek near the mouth of Babb's creek, and running across the south-east corner of Duncan and through the central part of Bloss and Hamilton to the Tioga river at Blossburg, from whence it passes through the centre of Ward to the county line. Entering Bradford county through the centre of Armenia, it crosses Troy, in Troy township; runs on through the south part of Springfield, Smithfield and Ulster, crosses the Susquehanna river near the mouth of Sugar creek, and then seems to continue its course through the middle of Wysox, north-west corner of Herrick, south-east corner of Orwell and north-west corner of Pike, into Susquehanna county, and on towards and into the State of New York.

The great curve, to the south of its true course, thus described by the Blossburg synclinal axis as it approaches the Susquehanna is very remarkable, but corresponds with a similar curve made by the Towanda synclinal axis as it approaches the river. Both of these lines resume their normal east northeast direction after crossing the river. There must be some deep-seated and far-acting cause for this deflection. It is made more striking by the comparative straightness of the intermediate Towanda creek anticlinal axis. Yet this latter also shows

that it sympathises with the movement by a slight but decided similar curve south of Towanda.

In Tioga county the axis of the Blossburg synclinal runs through the mountain much nearer to its north than to its south side.

The drainage of the basin in Tioga county is to the south-west. In Elk township, Slate Run, Cedar Creek and Mine Hill Run, descending from the Kettle Creek highlands, make deep gorges through it. Babb's fork of Pine Creek, with its two main forks, Wilson's Creek and Stony Creek, drains its middle mass, the Antrim Coal Field. Tioga river drains, northwards, the cup-shaped east end of the mountain basin, or the Blossburg Coal Field.

Zimmerman's Creek, the Block House Branch of Pine Creek, Roaring Branch of Lycoming Creek, East and West Mill Creeks and Sugar Works run drain the southern part of the mountain mass south of Blossburg.

Tioga river rises in a tamarack swamp on the eastern crest of the Armenia Mountain, and is first known as Tamarack Creek, until it is joined by Morgan Creek and other small streams at the county line, after which it is known as the Tioga River. Its general course for the first twelve or fifteen miles is to the south-west, keeping along the synclinal axis at the bottom of the basin. At the mouth of Carpenter's Run, about two miles above Blossburg, it turns north, and after running about five miles escapes from the mountains into the Mansfield and Wellsboro' anticlinal valley, about a mile and a half above Covington. The point where it turns to the north is in the deepest part of the oblong oval basin of the Blossburg coal field.

Inside the basin the Tioga river is joined by the South creek, Fall Brook, Carpenter's run, Taylor's run, Morris run, Coal run, Johnson creek and East creek, all rapid streams, descending with the dip from the oval rim of the mountain, cutting deep furrow-like vales, and removing thousands of acres of coal lands which once existed, and a pile of coal measures of perhaps 2,000 feet in thickness.

The outside north wall of the basin sheds its water into Marsh creek, in Charleston; into Marvin creek, Elk run and Canoe Camp creek, in Covington; into Canoe Camp creek,

Corey creek and Elk run, in Sullivan, Tioga county; and into Spring creek, and other branches of Sugar creek, in Bradford county. All the branches of Sugar creek cut their valleys across the high hill country of Catskill rocks in Troy, Columbia and Springfield townships, southwardly, making pretty deep valleys, and it is a very remarkable fact that Sugar creek receives almost no water from the Chemung belt to the south of it.

Catskill red rocks (IX) occupy the lower half of the mountain side in Tioga county. Vespertine gray rocks (X), with occasional red beds, reach nearly to the top of the mountain.

The dip is always southward in towards the heart of the mountain, or centre of the basin, and is strongest in inclination just at the foot of the mountain. The south dip in the north wall of the basin being steeper than the north dip in the south wall. But the south dip along the north side of the Blossburg basin is much less steep than the corresponding south dip along the north side of the Towanda basin. East of the Susquehanna the dips are altogether more gentle and the basin much shallower.

The north dip was observed at many places in the vicinity of Ogden's Corners and Union Centre; north-west of Canton; near Alba; near East Troy; and in the banks of the Susquehanna, opposite and a little above Towanda.

The south dip was seen on Cedar creek, below the lumber camp of Mr. S. X. Billings; on Pine creek, in Morris township; at the forks of Stony Fork; on Wilson creek, at the flag-stone quarries of Mr. L. Knapp; along the Tioga railroad, midway between Blossburg and Covington, and at many other points in Tioga county; and in Bradford county, near Columbia Cross-Roads; at Leona; and at Ulster.

Red Catskill outcrops (IX) are frequent, especially along Cedar creek, Pine creek and Babb's creek, with their tributaries, where Formation IX is often seen at the surface. But perhaps the best exposure of these beds is along the Tioga railroad, between Blossburg and Covington, in Tioga county. Other localities are along Sugar creek; at Long's mill's, below Troy; and along Leonard creek, at Salisbury's mill, in the edge of Troy township, Bradford county.

The Vespertine (Upper Catskill, X) may be seen along Babb's creek; in the narrows below Blossburg, where the lower beds are exposed, at their junction with IX; in the side of Big Mountain, between Blossburg and Covington; in the narrows, two or three miles above Blossburg, Tioga county; and at "Prospect Rock," on Mount Pisgah, in Bradford county.

The Umbral red shale, (XI,) from its softer nature, is not often seen at the surface, except in small ledges on the mountain tops.

The Seral Conglomerate (XII) is exposed along the mountain tops west of Cedar creek, in Elk township; along the railroad a little north of Antrim; and at many other points in the vicinity of Blossburg.

The Coal Measures may be studied at Antrim, Arnot, Blossburg, Morris run and Fall Brook, and especially on Coal run, near Blossburg.

The Catskill rocks are thinner in the Blossburg basin than in the Towanda basin by two or three hundred feet. In all other respects the description of one will apply to the other.

On the southern side the Catskill red rocks spread out over the hills for one or two miles from the south foot of the mountain.

In the Wellsborough region the Catskill red rocks spread over a still higher hill country as much as five miles from the north of the mountain.

The extent of ground covered by the red Catskill will be understood best by reference to the map of Tioga county accompanying this report.

The Catskill red rocks sweep round the east end of the Armenia mountain through Columbia and Troy, Southern Springfield and Northern West Burlington, supporting three elevated patches of the Vespertine (X) as shown upon the map, one of which is Mount Pisgah.

The broad and shallow basin continues eastward through Smithfield, Burlington, Ulster, North Towanda, Sheshequin, Rome, Wysox, Standing Stone, Orwell, Herrick, Pike and Warren; and everywhere capping the hills, more or less red strata are seen interstratified with gray, the age of which, owing to

the presence of Chemung fossils, I cannot satisfactorily determine.

It seems as if the true non-fossiliferous red Catskill beds of the Blossburg mountain range cease at Mount Pisgah, and are only represented further east, if at all, by strata capping a few hills in Wysox, Standing Stone and Herrick.

In Tioga county, Catskill rocks may be seen on Cedar creek, Pine creek and other streams. At the forks of Stony Fork, near a school house, red shale is exposed, dipping rapidly to the south. Under the red shale lie fifty feet or more of gray shale and sandstone, containing a *linguloid* shell.

Crustacean Tracks.—In the gray beds we found a very unique specimen of a different character—the track of some small, crab-like animal with a caudal appendage. The tracks are merely series of points arranged in two irregular lines across the surface of the stone, and about three-fourths of an inch apart. The mark of the tail is drawn very distinctly between the two lines. The points are also very distinct. The tracks are four or more in number.

Under these beds of gray shale and sandstone lie fifteen or twenty feet of red shale and sandstone. A little farther north the rocks have not so sharp a dip. This locality is in the Lower Catskill.

The "Red Rock" Fish Bed.—Midway between Blossburg and Covington, on the Tioga Valley railroad, in a cut, at a place called "Red Rock," red shales and sandstones (IX) about 200 feet thick are exposed, dipping rapidly to the south south-east. This is a noted locality for abundant remains of those remarkable fish which characterize the Catskill formation. Occasional bones are scattered throughout the entire mass; but only in one place in the series of beds are they found in considerable numbers, viz: between a calcareous layer and a bed of red shale. They consist of bones, scales and teeth, all in the most perfect state of preservation, the enamel of the teeth and scales retaining even something of the original lustre. The scales are all highly ornamented, and measure from a quarter of an inch to two inches or more in diameter, according to the species. Some of the teeth are an inch in length. These organic remains be-

longed to several different genera of armor-clad fishes, of which *Holoptychius* appears to have been the principal one.*

The exact junction of IX and X may be seen in the narrows below Blossburg, opposite the mouth of East creek. The top red shales of the Catskill are here seen passing beneath the bottom gray beds of the Vespertine in the bed of the Tioga river.

The Catskill rocks are also well exposed near Long's mills, below Troy; on Leonard creek, and around Mount Pisgah, Bradford county.

At Leona, on lands belonging to J. P. Doane, the Catskill is seen holding fish remains.

The following section was taken in the road just west of East Smithfield, and shows the elements of the beds there towards the bottom of the Catskill (IX).

East Smithfield Section, Tioga Co., Pa.

No.		Ft.
1.	Soft gray shale and sandstone with *fossil shells*—top of the hill	22
2.	Gray calcareous sandstone, with *fish remains*	1
3.	Red shale, with *ferns*, (*Cyclopteris?*) and *fucoids*	4
4.	Concealed space	3
5.	Gray shale and sandstone, with *ferns*	2
6.	Reddish shaly sandstone, diagonally laminated	12
7.	Soft gray shale	9
		53

Transition beds?—One mile north of this locality, along the Tom Jack creek, and considerably lower down, there is a bed of reddish shaly sandstone, thickness unknown, which is underlaid by gray shale.

There is considerable red rock in the road about two miles north of east from Smithfield, between the houses of E. P. Tracy and A. Arnold; also, near the house of W. A. Rice, in the south-west part of Ulster township; and again, near the forks of the road, on the hill, about two miles and a half west of south from Ulster village. At the latter place it contains *fish* remains.

*I well remember with what feelings of wonder I first beheld a specimen from this locality, filled with these bones and scales. It was after my curiosity had been awakened by the glowing descriptions of Hugh Miller, in his "*Old Red Sandstone*" and "*Testimony of the Rocks.*"

There is also considerable red shale and sandstone on the hill north of Black Ash Pond, in the south part of Sheshequin township.

"*The Red Rocks.*"—A little east of Wysauking, on the brow of the hill, there is a place called "the red rocks," where there is a ledge one hundred and fifty (150) to two hundred (200) feet high, which is composed of bluish shale, gray shale and sandstone, and reddish shale and sandstone. They dip to the north and contain a few poorly preserved *fossil shells.*

There is considerable red rock on the hills in the eastern part of Wysox, the southern part of Orwell, the northern part of Standing Stone, Herrick and Pike townships. At one locality, in the road, at the house of H. Parks, in Standing Stone, a red rock is seen containing *fish bones.*

I am fully convinced that, going to the westward, these strata gradually exchange their red color for some neutral tint, when they would be regarded, unequivocally, as belonging to the Chemung (VIII.)

Notes.—A short distance above the mouth of Sugar creek, at the Narrows, the cuttings of the canal along the West bank of the river expose the Chemung rocks for nearly a mile in continuous length, and forty feet high. The scenery is strangely picturesque. *The lines of stratification scarcely vary in their height above the water,* and almost every stratum is well marked and straight throughout that distance. But there is a concealed dip *into the hill* towards the south south-*west,* of as much as 12°.

Boulders of white limestone from central New York have been brought down the river in such abundance that lime kilns were formerly erected along the river, and canoes were used for collecting the material. The debris in the branch valleys is a heterogeneous mixture of northern and local drift. [F. R. 1858.]

CHAPTER VII.

WELLSBOROUGH ANTICLINAL.

The Mansfield and Wellsboro' anticlinal axis and valley lies between the Blossburg Mountain basin on the south, and the Crooked Creek (Mill Creek) Mountain basin on the north.

The axial line of the anticlinal crosses the west line of Tioga county about two miles and a half north from the south-west county corner;—runs through Elk township, crossing Cedar creek at its fork near an old school house, three-fourths of a mile north from the timber camps of Mr. S. X. Billings;—crosses Pine creek somewhere above Round Island;—passing two miles south of Wellsboro';—leaves Charleston township near East Charleston post office;—crosses Tioga river a mile and a half above Mansfield, near Canoe Camp; and proceeds through north-west Sullivan and south-east Rutland townships.

It enters Bradford county and Columbia township to the north-west of Austinville;—crosses the Williamsport and Elmira (Northern Central) Railroad near Snediker's;—passes Middletown in Ridgebury township;—crosses the Susquehanna river between Athens and Milan, and leaves Pennsylvania to enter the State of New York somewhere in Windham township.

When traced in the opposite direction, or towards the south-west, this anticlinal sends off a branch across Pine creek, through the northern portion of Elk township. Between these two anticlinals, in Potter county, lies what I will call, in my report on that county, the Kettle Creek Mountain basin. The eastern end of this synclinal is on Pine creek, as shown by the coloring of the map. The axis of the main anticlinal is deflected to a more south-west course, while that of its northern

prong pursues a westerly course. The synclinal begins where the two forks diverge.

It commences with merely a slight settling of the flat crown of the anticlinal. This trough rapidly widens and deepens to the south-west, until it becomes the Kettle Creek Mountain basin. It is in the north-western part of Elk township, between the head-waters of Elk run and Cedar creek.

Considering the wilderness condition of the country, and the fact that this basin only enters my district to a limited extent, I shall not attempt a detailed statement of it in this report. It properly belongs to the geology of Potter county. Let it suffice to say that the same conditions I have described as belonging to the Blossburg basin are repeated here. The Catskill constitutes the base of the mountain, and is succeeded in the ascending order by the Vespertine, Umbral, Millstone Grit, and perhaps the lowest beds of coal, along the county line. Where we crossed these mountains between Elk run and Cedar creek, we found them only capped by the Umbral; but numerous fragments of conglomerate indicated our proximity to the Millstone Grit.

The two diverging anticlinals are much diminished in force as they radiate from the point of separation.

The anticlinal valley divides (with the axis) west of Pine creek, one arm extending to the south-west, between the Blossburg and the Kettle Creek Mountain basins; the other extending to the west, along the south line of Gaines township, between the Kettle creek and the Mill Creek Mountain basins. Both these valleys are narrow compared with the main valley farther east around Wellsborough.

Through that portion of Tioga county lying east of Pine creek, the anticlinal valley spreads southward to the Blossburg Mountain basin, or to the outcrop of the Vespertine rocks, which is shown on the map, and may be indicated, approximately, by a line drawn from the north-west corner of Morris township, through the south-west corner of Sullivan township to the Bradford county line, at the south corner of Columbia township.

It spreads northward to the Mill Creek Mountain basin, or to the outcrop of the Vespertine rocks, which is also shown

upon the map, and may be very nearly represented by a line drawn from the mouth of Marsh Creek to the Bradford county line, near the south-east corner of Jackson township.

Its place may be seen by a glance at the county maps, which contain the names of the inhabitants, with their places of residence. It will there be observed that the belt of country embraced within the above described limits is much more densely populated than the mountain basins on either side; from which it may be correctly inferred that the arable lands are likewise mostly confined to the anticlinal.*

The Mansfield and Wellsboro' valley may be said to terminate at the Bradford county line, not by closing up, but by opening out into the rolling country lying to the north-east, over which anticlinal and synclinal areas have alike been so leveled down that the existing elevations vary but little in height; say 200′ or 300′ above the Tioga river bed.

The surface of the Wellsborough valley proper is rolling, consisting of a succession of hills and valleys, varying but little in general appearance; and the same features prevail through Bradford county. The soil is moderately good; as good, perhaps, as ean be found in the northern tier of counties; and the region may be considered rich in agricultural resources.

It is drained by the waters of Pine creek and the Tioga river, with such smaller streams as Elk run, in Gaines township; Cedar creek, Marsh creek, Stony Fork, Wilson creek, Catlin Hollow creek, Mann's creek, Elk run, in Covington township; Marvin creek, Canoe Camp creek, Corey creek, Elk run, in Sullivan, and Mill creek in Tioga and Rutland.

In Bradford county, it is drained by Sugar creek, South creek, Bentley creek, Orcutt creek and other branches of the Chemung river.

Pine creek† is a stream of considerable volume. From the mouth of Marsh creek all the way to Lycoming county, it flows in a deep and narrow valley or gorge, with high hills and walls of rock on either side. There are no flats of much consequence, the hills rising usually from near the water's

*The same feature will also be noticed in connection with the Wilmot, Towanda and Sabinsville (or Cowanesque) anticlinals.

†A translation of the Indian name, meaning, "River of the Pines."

edge. Having its sources in Potter county, it runs nearly due east after entering Tioga county, within the edge of the Mill Creek mountain basin, until it is joined by Marsh creek, when it takes a sharp turn to the south, cutting across the Mansfield and Wellsboro' anticlinal at the point where the axis divides. Its course is one of zigzags, across anticlinals and synclinals, from its sources in Potter county to its confluence with the West Branch of the Susquehanna at Jersey Shore. It is a rapid flowing stream throughout, while its principal tributary, Marsh creek, is a very sluggish stream—more like a cove.

Marsh creek is a remarkable stream, with a motion so slow as to be hardly perceptible. It flows through a broad valley, known as "the Marsh," the ground being swampy for many miles. Its direction is exactly the reverse of that pursued by Upper Pine creek: as if the waters of Pine creek once flowed up Marsh creek, straight on toward the Tioga river. In fact "the Marsh" extends the whole distance from Pine creek to Nile's Valley, near the north-east corner of Delmar township, where the water from Norris brook flows both ways, part down Crooked creek and part down Marsh creek. It is a remarkable summit, if summit it can be called, which divides the waters flowing down Marsh creek to Pine creek, and those flowing down Crooked creek to the Tioga river. The idea is therefore quite popular among the inhabitants that Pine creek, instead of flowing south to Williamsport, through the gorge first described, flowed formerly through the valleys of Marsh creek, and Crooked creek into the Tioga river. It is a curious topographical fact that a dam, fifty rods in length, from mountain to mountain, across Pine creek at the mouth of Marsh creek, such as it might be possible to build, and such as may possibly have been erected, for a time, by other than human agency, during the glacial epoch, would effect this diversion *

[*On the road from Wellsborough down Crooked Creek there is a low hog-back ridge, or natural dam, the lowest part of which is 12 feet above water-level, yet its edge comes within 60 feet of the marsh. A traveller may look to the right over the marsh which fills up the bottom of the valley, and to the left into a pond which has neither inlet nor outlet. The dam lies across the mouth of a cove in the high steep hill side and belongs to the category of so-called "moraines," whether produced by glacial ice or not. See Final Report, 1858, Vol. 1, p. 312.

The surface rock over the *southern* fork of the anticlinal south-west of Pine creek, belongs wholly to the Red Catskill (IX). The Chemung rocks (VIII) do not make their appear-

Mr. Sherwood has requested my answer to a question arising directly out of these facts, and in connection with what has been said on pages 6 to 9, chapter 1, above. He states the question thus:

"No one can doubt that all our valleys through Tioga and Bradford have been in the main produced by the agency of running water, and that this water in motion has been that of the present streams, operating through long periods of time, in the same manner and in about the same degree as in our own day. It is an accepted fact that through their instrumentality our valleys have been excavated, and the resulting sediments transported to the sea.

"But it is also conceded that while the Blossburg and Mill Creek mountains stand at an altitude of one thousand or fifteen hundred feet above the Tioga river, and six or eight hundred feet above the Mansfield and Wellsboro' anticlinal valley, the anticlinal valley marks the site of an ancient mountain chain, which exceeded in height the Blossburg and Mill Creek mountains by at least one thousand feet. To many this may seem a matter difficult to comprehend, since the conditions have become reversed in the process of time. But such is the lesson we learn from the rocks, which tell us that all the formations in the Blossburg and Mill Creek mountain basins, from the top of Formation VIII up to and including the coal measures, once passed over this anticlinal axis.

"We have every reason to believe that such were the topographical features at the time the streams commenced to excavate their channels. But how did the Tioga river first find its way from the Blossburg basin over and through the then existing Mansfield and Wellsboro' anticlinal *mountain* into the Mill Creek basin, and thence over and through the then existing Sabinsville anticlinal *mountain* into the Cowanesque basin?"

My reply may be briefly worded thus:

The main fact at the bottom of the explanation is this:—While our synclinals are parallel, they are not regular, but consist essentially of series of oval basins along the synclinal axes.

The *original* drainage must have descended to the centre of each oval basin, and then found its way across the anticlinal to the next oval basin of the next synclinal axis.

Follow out this idea, and take into account:—1. The different size of the different synclinals and anticlinals;—2. The universal general uptilt of the whole set towards the north;—3. The sudden termination or rapid declension of anticlinals at certain points;—4. Cross fractures;—5. The undercutting against the basset edges in the shales, letting down the sand-rocks; and 6. and chiefly, the *underground solution of the limestones* in a system of caverns, which when the roofs fell in constituted valleys—and you will easily make out the grand final result—the present system of drainage in zigzags; alternately parallel to and across the axes.

The first stage of the process was while the original drainage ran in the synclinals.

Theoretically, the great second stage of the process may be considered as commencing when the drainage had come to be transferred to the anticlinals.

ance in the bed of Cedar Creek, but they do at the forks of Elk run, where the *northern* fork of the anticlinal crosses that stream, while the hills are capped with Catskill (IX).

East of Pine creek, all the way to the State line at Waverly, the surface rock is composed of the gray fossiliferous shales and sandstones of the Chemung Group (VIII). In Tioga county the Chemung belt is narrow along the middle of the Wellsborough valley, with a red Catskill border on the north and on the south. The red border land *on the north* stops in Bradford county, sweeping around the end of the Mill Creek mountain, leaving only a few patches on the hills to the east; and the Chemung rocks spread to the State line. The red border *on the south* continues on past Mount Pisgah, as described in the last chapter.

Dips.—Over that portion of the valley between the top of the anticlinal axis and the foot of the Mill Creek mountains, the general dip is to the north north-west, as observed on Elk run; at the Mill of W. and C. B. Watsons, on Pine creek; below the mouth of Marsh creek; on Marsh creek; at Wellsboro'; on Hill's creek and Laub's creek; in the hills bordering the Tioga river between Mansfield and Laub's creek; along Mill creek, &c. It is stronger near the foot of the mountains, but more gentle than the south south-east dips. Three miles north of Mansfield a maximum dip, to the north, of 5° to 8° is visible.

Outcrops, though not extensive, are frequent and interesting on account of the large number of fossils which many of them afford. Most of the outcrops are of rocks belonging to the Chemung Group; well exposed at Round Islands, on Pine creek; at Wellsboro', along the C., C. & A. Railroad; two miles north of Mansfield, on Kelley creek; and also, in Bradford county, in the south part of Ridgebury township, on Fall creek, midway between Middletown and Smithfield Summit, where the *Chemung Conglomerate* is exposed.

The Catskill rocks, (IX,) from their position on the hills, are not often well exposed.

Actually, the transition was gradual, and through innumerable ages. The method pursued was in the main by undercutting in the soft rocks; and always diagonally across the dip. You will see this process going on now, according to this same method, in ten thousand places. J. P. L.]

The Chemung Rocks (*VIII*).—The description of Chemung rocks along the Towanda anticlinal axis, given in the last chapter, will apply to strata of the same age along the Mansfield and Wellsboro's axis, with this difference, that there is more shale and less sandstone, and more calcareous rock. The color is generally gray, bluish and greenish, with some of an olive tint. Towards the Susquehanna, and beyond it, red beds keep coming in on the south side of the axis, at lower levels; the material also becomes coarser, and more often obliquely laminated.

Area in Tioga County.—Chemung rock occupies a small enclosed area in Gaines, in the valley of Elk run, at its forks. It is also the surface rock in the south-east corner of Gaines, the north-east corner of Elk, the central part of Delmar and Charleston, the south two thirds of Richmond, the north edge of Covington, the north-west half of Sullivan, and the north-east half of Rutland townships, Tioga county.

Area in Bradford County.—Chemung rocks cover more than half of Columbia on the north, except a few small patches in the vicinity of Old Hickory post office; the north half of Springfield; part of Smithfield and Ulster; all of South Creek, Ridgebury and Athens, with most of Litchfield and Sheshequin.

Transition beds cover portions of Litchfield, Sheshequin, Rome, Windham, Orwell and Warren, east of the Susquehanna river. They also occur to some extent west of the Susquehanna river, over portions of Ulster, Smithfield and Burlington.

Chemung exposures.—At the forks of Elk run, in Gaines township, an excavation (for coal) has been made into a bed of dark-colored, shaly, calcareous rock, belonging to this age, and containing fossil shells.

On Pine creek, where the road descends the hill to Round Islands, some three hundred feet or more of Chemung rocks are exposed, containing fossils.

This is perhaps one of the most extensive outcrops along the Mansfield and Wellsboro' anticlinal. Even the top of this thick mass is not visible in the deep vale of Cedar creek, in Elk township; showing a considerable and rapid decline of that arm of the anticlinal axis in its south-west direction.

There is probably a similar declension of the other one of the two arms into which the Mansfield and Wellsboro' axis divides at Pine creek; for the topmost strata only of the Pine creek exposure are barely visible at the bottom of the Elk Run valley. Both anticlinals die down with the deepening of the Kettle Creek Mountain basin.

In Delmar township, half a mile south of Stony Fork post office, in the west bank of the creek, a well has been bored three hundred (300) feet deep for salt, on the site of an old salt lick, through rock belonging to the Upper Chemung. A considerable stream of water flows from the well continually, perhaps enough to fill a two-inch pipe. It is pretty strongly impregnated with salt.

Fossils.—In the quarries back of Wellsboro', and in the railroad cut below the dépôt, Chemung strata are exposed dipping north north-west. These are sandy, shaly and calcareous beds of a gray and bluish color, containing *Productus hirsuta*, and *P. Boydii; Spirifer disjunctus*, and *S. mesacostalis; Rhynchonella contracta*, *Athyris angelica*, *Streptorhynchus pandora*, *Grammysia elliptica*, and other species.*

Iron Ore.—In Charleston three-fourths of a mile west of the house of J. Rouse, in the main road, there is a thin vein of iron ore, fifteen inches or more in thickness, which has a peculiar seedy structure. It is the second vein, of which I shall make mention hereafter.

The following results were obtained from a partial analysis by Mr. A. S. M'Creath:—

Iron	31.800
Sulphur	.034
Phosphorus	.253
Insoluble residue	35.120

*The limestone is found in the hill back of the court house, in Wellsborough, in numerous bands, the uppermost and lowermost probably 100 feet apart. It has an aggregate thickness of many feet of fossiliferous rocks. The Mansfield iron ore underlies the plot of ground on which Wellsborough is built. An excavation made anywhere to the depth of three or four feet will develop a band of sandy iron ore about five inches thick.

One mile and a half from the town, on a road leading south, there is a deposit of *travertin* in an extensive dry bog, covering an acre, and from six inches to three feet deep. It has been burnt, and makes very fine white lime. It has been brought down from the hills by rills, and fixed in a bed of moss, the organic structure being very visible.—J. P. L. in final report 858, Vol. I, p. 312.

Coal.—In Charleston township, about a quarter of a mile south of Dartt Settlement, on the banks of the creek, is located the "Arienio Shaft," sunk in *Chemung* strata for *anthracite coal;* and at a cost, it is said, of from ten to twenty thousand dollars. It is a matter of wonder how intelligent men could be duped into an expensive search for anthracite coal where there is not the slightest evidence of its existence, but where a thousand facts prove that no such mineral can possibly be found.*

Fossil.—In Charleston near the house of C. Patridge, where the road crosses Hill's creek, and perhaps two or three hundred feet below the top of the Chemung, there is a thin layer of shale containing specimens of a curious fossil known as *Dictyophyton tuberosum*—the same species as those found at Bath, New York, and which I have never seen elsewhere in this State, except at one other locality.†

In Richmond township, south-west part, half a mile east of O. A. Benedict's we found a thin vein of iron ore six or eight inches thick, having the same peculiar seedy structure as the ore found in Charleston township. It is the second vein.

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*The excitement about this *ignis fatuus* was kept up during months and even years. "Basket picnics," were advertised with clever speakers, music, etc., when the coal was to be "opened." Of course it always happened at such times as the shaft still lacked a few inches of getting down to the coal. Sooner or later these repeated and inevitable disappointments will have their wholesome effect; but the hole in the earth will remain as a warning to others who may be inclined hereafter to embark in similar wild projects.

†Prof. Hall describes it as follows:—

"Stem hollow, obconical, rapidly expanding above. Entire surface reticulate by longitudinal and transverse striæ, and marked by several series of longitudinal subangular nodes, which are continued across the intermediate space by a sharp slightly elevated ridge.

"These remains are usually casts in sandstone, though sometimes preserving the exterior markings; while in many instances they consist of impressions of the exterior preserved in the rock, and though occurring in the same beds with land-plants, never preserve the carbonaceous coating common to the latter. From this fact, and from other circumstances, we are led to infer that they belong to the marine vegetation, and that they are Algæ of a peculiar form and mode of growth."

[A remarkable increase in our knowledge of this curious fossil has recently been made. Prof. Hall has obtained specimens from a rich locality in Northwestern Pennsylvania, showing the sides as well as the base covered with the basket-work markings characteristic of the species.—J. P. L.]

Upper, First or Mansfield Ore Bed.—About three miles from Mansfield, a little south of west and along the road to Wellsboro', is located the ore bed which has mainly supplied the furnace* at Mansfield for many years. It is from two to three feet in thickness, overlaid by twenty-five feet of gray shaly rock, and having a very gentle pitch to the north north-west. It is the highest of several beds found in the Chemung rocks of Tioga, and Bradford, and is not characterized by the *fish remains occurring in the lower beds.* Its fossils consist mainly of *Spirifer and Productus.*

Several thousand tons of this ore have been mined and manufactured into iron, which is of good quality, especially, when the ore is mixed with Lake Superior ores.

An analysis of a specimen of this ore, by Mr. A. S. M'Creath, is as follows:

Iron	38.900
Sulphur	.063
Phosphorus	.603
Lime (existing chiefly as a carbonate)	13.100
Magnesia	2.140
Insoluble residue	11.565

The same bed crops out in the road half a mile farther west, twenty-five feet beneath a bed of red shale.

The same bed, probably, shows itself about two or three miles to the north, along Lamb's creek, on lands of William O. Ripley, and again in the banks of the same stream, opposite Mr. Day's, on lands of G. R. Wilson.

At Wilson's bank it is eighteen inches thick at the outcrop, but, as it seems to cover a large territory, it may be thicker or thinner at other points.

A partial analysis by Mr. A. S. M'Creath shows:

Iron	32.400
Sulphur	.065
Phosphorus	.585
Lime	9.170
Magnesia	2.918
Insoluble residue	23.890

On Ripley's land the bed is two feet thick, but contains a large percentage of calcareous matter. It quarries readily into large square blocks, which have been used for building arches

* The furnace at Mansfield was erected in the year 1854, since which time it has been operated at intervals.

under boilers in saw mills, and found to resist the effects of fire admirably. The dip is north north-west.

The same "Upper Vein" occurs again to the east of these localities, on the opposite side of the Tioga river, and on lands of Mrs. Lydia Lamb; also at several points farther east, on Pickle Hill. At these places the thickness ranges from one to three feet, the dip being to the north north-west; and a few feet beneath the ore occurs a bed of red shale. At one point it has been mined to some extent. A partial analysis of a specimen from Andrew Shaw's farm gave the following results (M'Creath, A. S.):

Iron	42.800
Sulphur	.018
Phosphorus	.903
Insoluble residue	21.670

Middle or Second Bed.—In the south bank of Mann's creek, a little above D. H. Clark's, and on land of G. R. Wilson, we found a bed of ore from twelve to fifteen inches thick, but probably not rich enough to be of much vale. It is a second bed, *lying from two to four hundred feet below the first or upper bed*, and I suppose it to be representative of the Roseville and Austinville ore; as it is characterized by the same kind of *fish remains.*

Lower or Third Bed.—About a mile from this place there is a third vein cropping out in the very bed of the Tioga river back of Shaw's, and *from one to two hundred feet below the second.* As the river has removed the upper portion, it is impossible to state the thickness. Five to ten inches remain, of more than ordinary quality, but *containing small flattened pebbles of quartz.* The following analysis, by Mr. David M'Creath, would show it to be the richest ore I have met with in my district:

Iron	43.100
Sulphur	.018
Phosphorus	.657
Lime	1.800
Magnesia	.922
Insoluble residue	20.910

The Second bed has been opened on the hill about seventy-five rods north-east of this spot, on lands of G. R. Wilson, where it was said to be sixteen inches in thickness. It has the same peculiar seedy (oolitic) structure, so common in this bed.

An analysis of a specimen by A. S. M'Creath, gave the following results:

Sesquioxide of iron	44.571
Sesquioxide of maganese	traces
Alumina	8.295
Lime	5.250
Magnesia	1.448
Sulphuric acid	.125
Phosphoric acid	3.854
Carbonic acid	none
Water	5.166
Insoluble residue	30.550
	99.259
Iron	31.200
Sulphur	.050
Phosphorus	1.683

Burlington Limestone?—Still farther to the north-east, on the same farm, near the top of the hill and considerably higher up, there is a bed of limestone or calcareous rock, said to be six feet in thickness, which has been worked quite extensively to supply a flux for the iron furnace at Mansfield, for which purpose it seems well adapted. It has also been burned for lime.

It is largely composed of *comminuted sea shells*, which must have been ground up and broken to fragments by the action of the waves. The dip is northerly. Is this bed the same as that worked by W. B. Kline at Burlington, in Bradford county? Is it the same as that referred to as occurring two miles north of Mansfield, by Richard Cowling Taylor, in his memoir on the Blossburg Coal Fields? Its properties will be seen by the following analysis by David M'Creath:

Sesqui-oxide of iron	2.142
Alumina	2.269
Lime	28.872
Magnesia	1.117
Sulphuric acid	.087
Phosphoric acid	.729
Carbonic acid	23.227
Insoluble residue	41.700
	100.143

The second bed of iron ore has been opened south-west of Mansfield, on Whipple's Hill, where it has been mined to some extent. The rise of the strata to the south brings it near the top of the hill, far above the locality on Wilson's land, last mentioned.

It also exists in the next hill to the north, but lower down, on lands of Dr. Joseph P. Morris and Albert Sherwood.

It has also been opened on the opposite side of the river, on Bixby's Hill, where considerable quantities have been obtained and ground into paint, of which it makes a good article for many purposes.* An analysis by David M'Creath is as follows:

Iron	35.300
Sulphur	.026
Phosphorus	.215
Lime	4.740
Insoluble residue	28.845

The second bed has been opened on the opposite side of the anticlinal axis, near the mouth of Elk run.

We found it exposed also on a small stream half a mile east of Covington, but only about eight inches in thickness. The dip is to the south south-east. A partial analysis by David M'Creath, is as follows:

Iron	24.000
Sulphur	.017
Phosphorus	.213
Insoluble residu.e	51.390

Kelly Creek Section.—There are no red rocks at Mansfield; but the character of the beds will be seen by the following section on Kelly creek, two miles to the north, the horizon of which is from one to three hundred feet below the top of the Chemung:

Chemung Rocks on Kelly Creek.

1. Sandy shale and beds of hard gray sandstone, with occasional pebbles of quartz (*Chemung conglomerate?*), 25′
2. Soft gray and bluish shale 45′

[*The ore was opened about 50 feet below the hill top, one mile south of Mansfield; the hill being about 200 feet high, and composed of flaggy, calcareous and sandy shale, of grayish and dove tints, abounding in *fossils*, which lie chiefly in the calcarcous layers, although fossil *casts*, are also abundant in the sandy beds, and in the red layers of the ore. My section here (at Boxby's diggings,) was as follows:—

Slate, sandy and argillaceous, calcareous	5′ 0″
Red sandstone ore	0′ 6″
Shale and slate	6′ 0″
Main ore bed; deep purple brown; ground to make paint; sometimes oolitic; from twelve inches to	1′ 3″

I was disposed to identify this ore with a bed of ore which I found on Pine creek, on the road to Coudersport, 13 miles from Wellsborough. See Final Report of 1858, Vol. I, p. 311. J. P. L.]

3.	Gray sandstone, with calcareous bands	6′
4.	Bluish shale, containing many *Lamellibranchiates* and large numbers of *Productus Boydii*, *Athyris angelica* and *Spirifer mesacostalis*	4′
5.	Bluish shale, with calcareous bands	4′
6.	Gray sandstone	4′
7.	Gray shale	8′
8.	Bluish and greenish shale and calcareous rock, with fossils	34′
9.	Gray and greenish shale	12′
10.	Concealed	24′
11.	Bluish calcareous rock, with fossils	6′
		172′

Building Stone.—About two miles from Mansfield, up Corey creek, on land of S. Longwell, there is a stratum of bluish sandstone, which has furnished some excellent building material.

The Second Ore Bed.—East from Mansfield, bed number two, iron ore, is exposed in the side of Oak Hill on lands of J. C. Howe; also in J. B. Clark's hill. At these places it ranges from eight to twelve inches in thickness.

In Sullivan township it crops out on the farms of John C. Clark, Jesse Rumsey, A. Richmond and Mr. Aldrich. On the three farms last named it is two feet thick, and on the last it has been worked to some extent. It appears to increase in thickness in this direction, while the quality is much better.

Flagstone Quarries.—About a mile and a half north of Mainsburg, on top of a hill, is located the celebrated flagstone quarries, which are furnishing large quantities of stone to the cities and towns of Southern New York and Northern Pennsylvania. Flags are obtained here of any desirable size, from one foot in breadth up to twenty or more, and as smooth and true as a plank. It is a desirable and valuable stone, and lying near the surface, is quarried at a very slight expense, The horizon is *near the top of the Chemung.* The dip is south south-east. The flags are non-fossiliferous, though most of the strata in Sullivan township are filled with fossils.

The Second Ore Bed, at Roseville, in Rutland township,* is said to be four feet thick. Whatever the thickness may be, the quality is good. It has been mined to some extent and ta-

[*The Roseville Ore beds on Mill Creek, three miles from the county line, was reported by me in 1841 to Prof. Rogers as having been long opened be-

ken to the Mansfield furnace. It is underlaid by light gray or greenish rock, and overlaid by three feet of gray and reddish concretionary sandstone. The dip is north-north-west. A partial analysis of a specimen resulted as follows (A. S. M'Creath):

Iron	41.900
Sulphur	.035
Phosphorus	.389
Insoluble residue	28.950

The same bed makes its appearance a mile and a half north-east of Roseville, on land of H. Wood.

In Bradford county, we found some good surface indications of this bed, on the farm of Albion Budd, in Columbia township. Pieces of ore of a very good quality are strewn over the ground, but we could not find it in place without excavating.

Fish in Ore.—At Austinville, about three miles farther south, the second ore bed has been mined quite extensively, and several thousand tons taken to Elmira, N. Y. It is said to be from six to seven feet thick, but two feet of this is not very good ore. The dip is south south-east. The ore at the mine contains fossils, and has yielded large numbers of *fish remains*, most of which have gone to the New York State Museum, at Albany. About a year ago other specimens were sub-

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fore that date. My section of the rocks containing it is given on page 311, Vol. 1, Final Report, 1858, thus :—

Top shale.	
Red ore, *two inches*	0′ 2″
Large balls of poor ore in shale	2′ 0″
Red sandstone	3′ 0″
Red ore balls	2′ 0″
Gray slaty sandstone	3′ 0″

"The ore is a red, sandy, soft stone, blood red in the streak; it lies in flags, like the Vespertine [Upper Catskill] sandstone, each of which is an inch or two in thickness. The mass is two feet thick; but above it, after an interval of three feet of red sandstone, are huge balls of another variety, apparently more sandy, and certainly of less weight.—It lies about 200 feet below the top of the Vergent [Chemung] Series.—It is observed in many of the neighboring hills; sometimes so soft as to be used for red chalk.

"In passing northward the ore is seen in many places along the road to Elmira, and returning towards Columbia Flats; but none towards Troy. It is found on the hills at Mansfield; and many tons of it have been thrown out at a point on the road four miles from Mansfield towards Wellsborough. Here it is accompanied by and is itself in the form of red shale, filled with innumerable fossils similar to those of the limestone, which, however, was observed in none of these places."]

mitted to Prof. J. S. Newberry, who pronounced them new.* They are generally fragmentary, and consist mainly of bones, there being but few, if any, scales or teeth. The bones retain their natural color, which contrasts so strongly with the red color of the ore in which they are imbedded, that they are readily discovered. The size of the bones indicates fishes of large size.

Heretofore the Catskill Group has been regarded as being peculiarly rich in the fossil remains of *fishes;* but I am convinced that, in the size and number of its species, the Chemung Formation, especially in its upper members, far surpasses it.

A partial analysis of the Austinville ore resulted as follows (M'Creath, A. S.):

Iron	33.600
Sulphur	.018
Phosphorus	.179
Insoluble residue	40.690

The Second ore bed we found again at a place about half a mile south-west of Columbia Cross Roads; and seventy-five rods west of the Williamsport and Elmira (Northern Central) Railroad, we found the same vein. It is about four feet thick.

It yielded to an analysis (M'Creath, David):—

Iron	32.400
Sulphur	.130
Phosphorus	.288
Insoluble residue	40.130

At Snedekerville more than two hundred tons of what is absolutely nothing but reddish brown sandstone rock have been excavated by an English miner, who professes to find minerals by "gauging." He had persuaded his employers that this worthless material was iron ore.

There are indications of iron ore at a number of places along the road from Snedeker's to Springfield; and about a mile

[*Dr. Newberry has described and figured two species in recent Reports of the Geology of Ohio, Vol. II, Part II, Palæontology, Columbus, 1875, pages 61 and 64. Plates LXVIII, pgs. 17, 17*a*, 17*b*, and Plate LVIII, pg. 18, under the names *Dipterus Sherwoodi* and *Heliodus Lesleyi*, the *dipterus* being a new species and the *heliodus* a new genus, but the places where these species were found will be described in a subsequent portion of this report.]

north east of Springfield, near the house of S. D. Harkness, it crops out in the road; and again, about two miles west of Smithfield, near the house of Mrs. Tracy. Beyond this, towards the Susquehanna river, we have seen but slight traces of ore.

Doubtless the time will come when some of the ores here described will prove valuable, more especially those in the vicinity of the Bradford-Tioga county line.

Chemung Conglomerate.—In the south part of Ridgebury township, on Fall creek, half way from Middletown to Smithfield Summit, there is a place called "the Silver Mine," where there is a bed of *white sandstone* and *conglomerate*, from fifteen to twenty feet thick, and where considerable money has been expended in a vain search for silver. Its horizon is in the *Upper Chemung*, but it contains no fossils except the carbonized and broken stems of *plants*. The dip is slightly to the south. The following is a section at this locality:

Fall Creek Sandstone Section, Bradford Co.

1.	Gray shale and sandstone	12′
2.	(Concealed)	8′
3.	*Calcareous* rock, containing *fossil shells*, and causing a fall in the creek of twenty-two feet	1′
4.	Gray shale and sandstone	28′
5.	(Concealed)	25′
6.	Hard, light gray sandstone	10′
7.	Hard, quartzose, white sandstone and *conglomerate*.	20′
8.	Soft gray and bluish shale, containing *Rhynchonella*,	16
9.	Hard gray sandstone	3′
10.	Soft gray shale	3′
	Total exposures	126′

A principal feature of the sandstone and conglomerate (No. 7) is its false-bedding, or oblique lamination. I have always regarded this rock as the representative of the conglomerate of Chautauqua county, in Western New York, as I have found a similar rock, which I believe to lie at the same geological horizon, at intervals, in various localities in every county between Chautauqua and Bradford.

In the main road about a mile south of the spot last mentioned, and perhaps one hundred and fifty feet higher up, there is a bed of weak iron ore, the horizon of which is not far below some red rocks.

To the north, down the creek, the rocks are gray, and contain fossils, among which we noticed *Strophodonta perplana* and *S. Cayuta.* Half a mile below, in the road-side, are indications of some good quarry stone.

Fragments of the above conglomerate are seen on the surface at several places in Athens and South Creek townships, especially in Wolcott Hollow.

Cash Creek.—In the bed of this stream, near Ulster, gray rocks dip, if anyway, slightly to the south.

"*The Narrows.*"—About three miles below Ulster, at a place called "the narrows," some three or four hundred feet of gray rocks are exposed. (See note to last chapter).

In Deerlick creek, Sheshequin township, one hundred feet of gray and blue shaly rock are exposed, but containing no fossils.

Flagstone.—In the lower part of Sheshequin, two miles south-east of Horn Brook post office, there is a valuable flagstone quarry; color, bluish and gray. It has been worked somewhat extensively. The dip is southerly.

Wysox Creek.—At the bridge over the Wysox, near the south line of Rome township, gray rocks are exposed, having a considerable dip to the south.

White Sandstone.—On the line between Rome and Windham, about three fourths of a mile north-west from North Orwell, on a hill, the surface is strewn with boulders of gray sandstone, weathering white.

A New Synclinal.—A little out of North Orwell, to the north-west, and in the bed of the creek, twenty or thirty feet of gray shale and sandstone are exposed, without fossils, and dipping *slightly to the north.* This latter circumstance, taken in connection with the topographical features of the region, and the fact that reddish rocks occur on the hills through Windham and Warren, have led me to infer that a *subordinate synclinal* axis exists here, starting somewhere in the north line of Smithfield, and keeping along the line between Sheshequin, Rome and Litchfield, and passing through the south part of Windham, the north part of Warren, and leaving the county near its north-east corner.

About a mile above Allis Hollow post office, in Orwell township, on Johnson creek, and near a saw-mill, gray rocks are exposed, having, apparently, a *considerable south-easterly* dip.

At the State line, in Windham township, on a branch of the Wappasenning, and near the House of Robert Howell, thirty or forty feet of gray shale and sandstone are exposed, containing *Bellerophon* and *Loxonema*.

Thickness of the Chemung (*VIII.*)—The aggregate thickness of the Chemung rocks exposed along the Mansfield and Wellsboro' axis is probably not less than six or seven hundred feet. The subject of the varying thickness of the formations will be discussed at the end of this report; but, it may be said here, that there is no place in the district where the thickness of the whole formation can be seen.

NOTE.—Two features of the synclinal belt of the Blossburg Mountain become visible on the colored map when all the observations are properly placed upon it:—

First and chiefly, the splitting of the basin eastward after passing the Susquehanna river.

Secondly, the appearance of a local anticlinal south-west of Blossburg.

Dips are seldom to be *measured* in a region like this; but some very significant exposures are designated on the map, viz: *south* dips near Middletown, Ridgebury township; *south* dips near Ulster; *south-west* dips along the river above Sugar creek mouth; *south* dips on the Wysox creek, where it enters Wysox township; *south south-east* dips on a branch near Alles Holley P. O., South Orwell township; and one *north* dip between W. Windham P. O. and N. Orwell P. O.

Between the last two mentioned dips must run an anticlinal axis through Rome, Orwell and Warren townships, towards Silver Lake, in Susquehanna county.

This anticlinal lies between the Towanda and Wellsborough anticlinals, and must die away against the general south and south-west dips along the Susquehanna river. Its existence explains the sharp bend to the south of the Armenia (Blossburg) synclinal as it approaches Towanda from the west.

On each side of it must lie two synclinals, one through Wysox and Pike, which represents the great Armenia (Blossburg) synclinal; the other, through Sheshequin and Windham, which may be taken as a more northern fork of the same.

If we could get a measured section through Litchfield, Rome and Wysox, we should probably see that the Sheshequin fork of the synclinal lies much higher above sea level than the Wysox fork, or main synclinal; and this is the reason why all the dips west of the river seem to be to the south, obliterating not only the Rome anticlinal, but the Sheshequin synclinal.

The true cause of the disturbance is no doubt to be sought in the fault in Standing Stone township, described above on page 39.

It is very interesting to see that the Sheshequin synclinal axis is almost a perfectly straight prolongation of the Blossburg synclinal axis but mounted, as it were, one step in the air; and this extra elevation of the geological horisons east of the river is no doubt the reason why the main red beds are only left on the west side of the river.

The other feature is analogous, viz: a subordinate anticlinal (?) sets back the south face of the Blossburg Mountain in Liberty township, Tioga county, and sends a prong of Catskill rocks into Lycoming county, north of Opossum run, to Oregon Hill P. O.

If this be a well marked anticlinal it must die in the body of the Blossburg Mountain eastward. It has had the effect however of showing the Arnot Coal basin out of line with the Blossburg Coal basin somewhat towards the north-west, as shown in the map.

As we are not yet prepared to report on the Coal Basins of Tioga and Bradford county, no more need be said here respecting this feature of the map.

CHAPTER VIII.

CROOKED CREEK SYNCLINAL.

The Crooked Creek (or Mill Creek) mountain basin lies between the Mansfield and Wellsboro' anticlinal valley on the south, and the Sabinsville (or Cowanesque Creek) anticlinal valley on the north.

Its south wall enters Tioga from Potter county, on the south side of Pine creek, which it crosses about three-fourths of a mile below the mouth of Marsh creek; runs thence to the north-east corner of Delmar; thence through the northern part of Charleston and Richmond; crossing the Tioga river at Lamb's Creek; and Mill Creek at the mouth of Elk Run; then sweeping around to meet the north flank at a point on the Rutland-Jackson line, a mile short of the county line.

Its northern wall enters Tioga from Potter county in the south-west part of Clymer township; crosses Long Run at its forks; passes along the southern edge of Chatham to the north-east corner of Middlebury township; crosses Crooked Creek at Keeneyville, and again near Hammond; the Tioga River about a mile south of Tioga village; keeping through the center of Tioga and the south edge of Jackson townships to meet the south wall of the mountain, as before described.

It is a much broken, mountainous belt of country, covering the northern half of Gaines, the northern two-thirds of Shippen, the south edge of Clymer and Chatham, the north part of Delmar, the northern edge of Charleston and Richmond, the north-west part of Rutland, the southern half of Middlebury, the south-eastern half of Tioga and the southern edge of Jackson townships.

Its central synclinal axis may be drawn upon the map as leaving Potter county and entering Tioga county in the north part of Gaines township, north-west of Gaines post office. Crossing Long Run between Blue Run and Benn Gully it makes a nearly east course through the north part of Shippen, across the head of Asaph and Canada Runs, to Middlebury, Centre and Hollidaytown. Bending a little to the north it crosses the Tioga River at the mouth of Mill Creek and enters Bradford county in the south-east corner of Jackson township. It crosses the Williamport and Elmira (Northern Central) railroad between State Line station and Gillet's, and leaves Pennsylvania to enter New York in the north-west part of Ridgebury township, south of Wellsburg; from whence it is prolonged past Owego to the north-east. This centre line of the synclinal is nearer the north flank of the mountain than the south flank, showing that the south dips are steeper than the north dips.

The general level of the mountain top, (or tops, for they are numerous,) is pretty uniformly at the same height above tide.

In the western part of Tioga county its surface drainage is into Pine and Marsh creeks, with their numerous arms—Phenix creek, Long run, with its branches, (Blue run, Gal run, Benn Gully, etc.,) Shin Hollow, Asaph run, Canada run, etc., and also into the upper branches of the Cowanesque—Mill creek and the Jamison.

Pine creek and Marsh creek have excavated their channels just within the edge of the basin; and it will be noticed that the point where these two streams unite and leave the basin is opposite its deepest part. The principal drainage is, therefore, out from the south side of the middle portion of an oblong oval basin. Of course it is here that a considerable area of coal measures has been preserved.

The mountain mass, which in Gaines township is cut completely through crosswise, and to its base, by Long creek flowing south into Pine creek, is cut up into three separate isolated knobs, further to the east, by Crooked creek and its branches, as the map will show. These streams cut the mountain through to its base.

Crooked creek has a curious course, entering the mountain basin at Keeneyville, and leaving it again at Hammond's, six or seven miles below, on the same side of the basin; but its course is through a somewhat shallower part of the basin. Crooked creek is here joined by some of its principal tributaries, as Norris brook, Catlin Hollow creek, Hill's creek, Steven House run, etc.

Mill creek joins the Tioga river exactly where the centre line of the synclinal axis crosses the river. Its principal feeders having their sources in the mountain, are Cabin run, Painter run, Bailey creek, etc.

It will be observed that the Tioga river cuts straight through the mountain, entering it at Lamb's creek and leaving it near Tioga. And the line of the Tioga river represents the transverse axis of another oblong oval basin similar to, but smaller than, the one mentioned before, in connection with Pine and Marsh creeks. This basin is only deep enough to retain the Coal Conglomerate on the mountain top above Painter run, a short distance east of the river.

The course of the Tioga river was evidently determined by, first, the oval basin of Blossburg, and secondly, by the oval basin of Tioga; and its direction from one to the other, N. 25° W. or at right angles to the course of the synclinal.

The geology of the Crooked Creek or Mill Creek Mountain differs but little from that of the Blossburg Mountain. The Catskill red rocks (IX) reach about half way up both sides, and the dip from both sides is towards the centre of the mountain.

The Catskill gray rocks (Vespertine, X) with occasional bands of red, make up the upper half and brow of the mountain.

The Umbral red shale (XI) or shales in which a red color predominates, forms the top of the mountain, and in the deepest part of the basin has considerable thickness.

The Seral hard white quartzose sandstone and conglomerate, (XII) or Millstone Grit, has been left here and there in patches on the Umbral surface, as on Painter Run, near the east line of Tioga township; and again at "the sand-bed barrens," westward from Niles Valley.

The Coal Measures are preserved (one or two hundred feet of the lowest part of them) only in the centre parts of the oblong basin in Gaines and Shippen townships, and farther to the south-west, in Potter county. These insulated patches are but the remnants of a once continuous and extensive coal field.

Beyond the end of the mountain in Bradford county, the Red Catskill (IX) caps two or three hills in the south-west corner of Wells township. Farther on to the north-east, the Chemung rocks (VIII) constitute the surface.

The steepest dips (and they are exceedingly gentle) are along the base of the mountain at the edge of the anticlinal valleys; and the dip towards the south is somewhat stronger than those towards the north. Examples of the south dip were noted at the forks of Long Run, in Clymer township; between Keeneyville and Middlebury Centre, and on Steven-House Run, in Middlebury township; along the Tioga River, in Tioga township; and at several points in Jackson township.

Examples of north dip were observed on Elk Run, in Gaines township; everywhere along Pine Creek, particularly near the mouth of Marsh Creek; in the west bank of the Tioga River, below D. L. and M. H. Fralic's steam mill, near the mouth of Lamb's Creek; on Mill Creek, at Brace's mill; in Bradford county, below the mouth of Orcutt Creek, in the banks of the Chemung; and on the opposite side of the River, between Waverly and Chemung, in the edge of New York State.

Exposures of IX.—The Lower Catskill may be seen to advantage near the mouth of Elk run, in Gaines township; at several localities on Pine creek, viz;—above the Elk Run bridge; at the mouth of Long run; opposite the tannery of Mr. S. X. Billings; near H. E. Cooper's; along the road at the mouth of Marsh creek, etc. Also, between Keeneyville and Middlebury Centre; on Steven-House run; in Shutter's hill, above Tioga; at the mouth of Mill creek; along the road below a bridge, midway between Mill creek and Lamb's creek; in the west bank of the Tioga river below Fralic's mill, and near the mouth of Lamb's creek; at Brace's mill, on Mill creek, and at innumerable other localities.

Exposures of X—Upper Catskill, or Vespertine may be seen almost anywhere in the side and brow of the mountains along

Pine creek, Long run, Marsh creek, Crooked creek, Steven-House run, Mill creek, Painter run, etc. Also, along the Tioga river, in the brow of the mountain below the mouth of Mill creek; in the side of the hill east of the Big Hill water tank; on Big hill, and in the brow of the mountain on the opposite side of the river.

Exposures of XI.—The Umbral shale, from its softer nature, and from its position at or near the top of the mountains, is not so often seen. The best localities I know of are on Painter run, in Tioga township.

Exposures of XII.—Outcrops of the Millstone Grit, or Coal Conglomerate, are frequent, and possess considerable interest. It is well exposed on Painter run, at "the quarry," north-west of the Loveless lumber camp, where it caps the mountains; also, to the west of Niles valley, at "the sand-bed barrens," where large masses have disintegrated, forming beds of pure white sand; and again, on the west side of the Asaph, and on the east side of Long run. The scenery in the neighborhood of these rocks is always highly picturesque, owing to their color, (which is white,) and to the broken fragments and detached masses scattered about over many acres.

Exposures of XIII.—The lowest beds of the Coal Formation are occasionally preserved towards the western part of Tioga county, in Gaines, Clymer and Shippen townships, but are not often exposed, except in the openings for coal. The best locality is at "the barrens," east of Long run, near the head of Benn Gully.

Catskill Rocks.—As around the Blossburg basin, where its thickness is greater by one or two hundred feet, the Catskill formation contains, besides sandstone and shale, beds of calcareous rock, or rough, impure limestone, which is in fact a breccia filled with fragment of slate. In these beds the finer material is generally of a more or less reddish color, though sometimes gray. The shales and sandstones are not always red, though this is the predominating color; there are intercalated beds of gray sandstone and bluish shale. Some of the sandstone layers have a micaceous character, being filled with small particles of mica. Among the sandstones false-bedding

is also a prominent feature, though perhaps not as much so as in the basins farther south.

The border of Red Catskill (IX) on the south side of the mountain laps over the north arm of the Mansfield and Wellsboro' axis west of Pine Creek, except a small area on Elk Run. From thence it runs along the base and south side of the mountain, in a belt from half a mile to three miles wide, through the south part of Shippen, the north part of Delmar, the north end of Charleston, the north part of Richmond, and the center of Rutland townships, to the Bradford county line, near the north-east corner of Rutland.

The border of Red Catskill on the north side of the mountain is narrower by a mile in its widest parts; which is partly owing to the sharper dip. It runs through the south part of Clymer, the south edge of Chatham, the centre of Middlebury and Tioga, and the south edge of Jackson townships, to the Bradford county line, in the north-east corner of Rutland, where it joins the belt on the south side, around the ends of the mountains. From thence it runs into Bradford county, capping three or four low knobs in the corner of Wells and Columbia townships, of which the one at Old Hickory post office (Aspinwall Corner's) is the last to the north-west.

Watron's Mill Section.—At the mill of W. and C. B. Watron's, on Elk Run, we found fifteen feet or more of red shale, overlaid by one or two hundred feet of gray and bluish shale and sandstone; over which again, farther down the creek, near the house of J. H. Watron's, lie other beds of red shale and sandstone, some of them twelve feet thick. Above these again lie one or two hundred feet of gray and bluish shale and sandstone, diagonally laminated in the lower half, and containing fossil shells in the upper beds. These are exposed near the mouth of Elk Run, from twenty to forty rods above the bridge over Pine Creek. The fossils are of well-known Chemung species—*Spirifer*, *Productus*, *Grammysia*, etc.

The dip of all these strata is north-westerly.

Elk Run and Long Run Section.

Gray soft shales, one mile north of Gaines, on Long Run, with *ferns*... Thickness unknown.
Interval of unknown thickness.

Gray and blue shale and sandstone, with *Spirifer*, *Productus*, *Grammysia*, &c....	100′ to 200′
Gray and blue shale and sandstone, false bedded.....	
Red shale and sandstone.....	Several bands.
Gray slate and sandstone, and bluish, on Elk Run; all north dip.....	100′ to 200
Red shale, on Elk Run.....	15′

Fern Bed.—One mile up Long Run, north of Gaines, where soft gray shales are exposed at a watering trough by the roadside, we obtained a number of *ferns*, the first found in Tioga county. There are several different kinds, some resembling fossil ferns found in Susquehanna Co., Pa., and Delaware Co., N Y., and others probably new. The horizon of these ferns is higher up in the Catskill than that of the shells mentioned in the preceding paragraph.

The Waddles Brook section (in the next chapter) is interesting as showing this fossiliferous character of the Lower Catskill.

Pine Creek Fossils.—Red, gray and bluish beds, occasionally containing fossils, are met with in the bed of Pine Creek at intervals all the way from Gaines to the mouth of Marsh Creek. A little below the mouth of Marsh Creek, along the road, there are twenty-five feet or more of north dipping gray sandstone, somewhat *calcareous at the top;* with traces of *fossil shells* in the upper part. It is underlaid by beds of red shale.

Plants.—Between Middlebury and Keeneyville, in the banks of Crooked Creek, a quarry of tolerably good flag and building stone has been opened in Catskill strata. dipping southward. The only fossils noticeable are carbonized *stems of plants*, which in places form thin seams of coaly matter.

Micaceous Red Shale.—At a quarry on Steven-house Run, in Middlebury township, there is a thin stratum of red sandstone highly charged with particles of mica. This is popularly suspected to be *specular iron ore* because the mica glistens.

Hathaway Ore.—In "Shutler's Hill," south-east of Tioga village, some two hundred feet, more or less, of Catskill rocks, principally red shale and sandstone, may be seen, dipping to the southward. These strata have been further exposed by excavations made in search of an ore, said to combine new and

wonderful properties. Indeed, the hill has been honey-combed with shafts and trenches, and much time and money wasted.

It has been claimed through the local papers that one pound of rock from this hill melted up with four pounds of old cast iron will convert the whole mass into steel. Four pounds of old cast iron, at two cents per pound—eight cents; four pounds of steel, at twelve cents per pound—forty-eight cents; value of the pound of shale used in converting four pounds of cast iron into four pounds of steel—forty cents. Razors, etc., said to have been made from steel thus produced, have been placed on exhibition about the country.*

Lamb's Creek Section.—On a small stream coming into Lamb's Creek, in Richmond township, from the north-west,

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*The real value of "Hathaway's Ore" and of the "Motor Metal," will be better seen from the following extracts from a letter of Mr. M'Creath, dated Harrisburg, Aug. 25, 1876:—

The specimen of "Hathaway Ore" you sent to this laboratory last March has been carefully analysed, with the following result:

Silica	59.630
Alumina	18.560
Sesqui-oxide of iron	8.571
Sesqui-oxide of manganese	.290
Lime	.672
Magnesia	2.252
Potash and soda	5.109
Sulphuric acid	.123
Phosphoric acid	.279
Titanic acid	trace.
Water	4.560
	100.046

The analysis shows that it is simply a ferruginous slate, containing the ordinary constituents of that rock, with a mere trace of titanic acid. The analysis has been very thorough and satisfactory. Nothing exists in the slate aside from what is mentioned in the above table. It contains no gold, silver, mercury, copper, tellurium or palladium.

I have likewise examined with great care certain alloys, so-called, which have been forwarded to me by Mr. G. W. Hathaway and Mr. T. G. Hall, and have made special tests for a "new metal" which they claim to have discovered.

It scarcely seems necessary to say that I have found nothing unusual in these substances. They are not alloys; unless an exceedingly silicious, cold-short, white cast iron can be termed an alloy. I have been especially careful in the examination of these substances, on account of the local interest manifested in the subject.

near H. Dorsett's, the beds, are exposed, dipping north north-west:—

Lamb's Creek Section. Catskill.

1.	Coarse gray sandstone (bottom of X?)	60′	
2.	Red sandstone (top of IX?)	12′	
3.	Concealed	5′	
4.	Gray sandstone with a reddish cast	5′	
5.	Concealed	50′	
6.	Red sandstone	10′	
7.	Red shaly sandstone	30′	
8.	Red sandstone	2′	
9.	Red shale, mottled with green	22′	
10.	Red sandstone	8′	
11.	Red shale	11′	
12.	Gray shale	10′	
13.	*Calcarous* rock, with well-known *Chemung fossils*	0′	10′
14.	Gray sandstone	12′	
15.	Red shaly sandstone	8′	
16.	Concealed	9′	
17.	Red sandstone (at the bottom)	2′	
	Total of rocks measured	256′	10′

Below this series, for an estimated distance of one hundred feet, the rocks are concealed. Then we come to gray and bluish beds belonging to the Chemung (VIII).

Seeley Creek Section.—One mile north-east of the last-named locality, and about four miles north-west of Mansfield, on another branch of Lamb's Creek, known as Seeley Creek, there is one of the finest and most interesting exposures of Catskill rocks within the limits of my district. The following section will show the order and thickness of the beds, with their fossil contents:—

Seeley's Creek Section; Catskill.

1.	Red shale, ten feet or more exposed	10′
2.	Red sandstone	20′
3.	Red shale, somewhat mottled with green, and bands of *calcareous* rock. Contains *fish* remains, *plants* and *shells*	4
4.	Red shale	12′
5.	Red sandstone	8′
6.	Red shale	34′
7.	Greenish shale, containing a *Lingula*	4′
8.	Concealed	4′
9.	Gray sandstone	2′
10.	Red shale	20′

11. Gray, *calcareous* band, containing *ten or twelve species of well-known Chemung fossils*.....	0′	6″
12. Gray sandstone.....	12′	
13. Red shale	6′	
14. Gray sandstone.....	2′	
15. Red shale	5′	
16. Greenish shale	4′	
17. Red sandstone.....	15′	
18. Red shale	5′	
19. Red sandstone, ten feet exposed.....	10′	
20. Concealed, at the junction of red and gray rocks known as Chemung and Catskill; estimated thickness.....	100′	
21. Gray Chemung shale, containing a bed of iron ore, eighteen inches thick (bottom of section),	15′	
	292′	6″

Among the plant remains in No. 3 of the above section, I have recognized a *Sphenophyllum* (*antiquum?*) Shells are not wanting, for I found in it the larger part of a well-marked *Orthonota.*

The fish remains in this bed are its chief attraction. I know of no locality in Northern Pennsylvania so rich in the remains of *Holloptychius*, *Bothriolepis*, *Dipterus*, and other large ganoids. To the casual observer they might escape notice, as it is only by the careful removal of the shale adhering to the thin calcareous slabs that the finer specimens are revealed. I think this spot promises much to the future investigator.

It was from this bed that I obtained the tooth of a new species of Dipterus described by Dr. Newberry, as *Dipterus Sherwoodi*, in Geology of Ohio, Vol. II, Part II, Palæontology, p. 61.*

*The following extracts from his description will show the character of this tooth and the interest which attaches to it:—

"Teeth one inch in length, triangular in outline; crown marked with three prominent tuberculated ridges, separated by deep furrows somewhat wider than the ridges. The strongest of these ridges forms one side of the triangular tooth. On the angle opposite this side are a few irregular tubercles, but no traces of distinct ridges. The denticles which crown the ridges are somewhat depressed laterally, are rounded, smooth, and blunt at the summit.

"This is apparently one of the upper palate teeth of a species of *Dipterus*, and is especially interesting, as being the first relic of that genus found on this continent. It can be readily distinguished from all the species described abroad, by the small number of its radiating ridges.

"In the same rock with this tooth are a number of imperfectly preserved rhomboidal or rounded scales, which are thick and strong, and have the upper surface punctate precisely as in the scales of the foreign species of *Dip-*

Bed No. 11 of the section is also rich in fossils, but mainly of a different character. Ten or twelve species of the most characteristic *shells* of the Upper Chemung are present in considerable number, associated with *fish teeth* and *crinoidal* remains. The height at which these fossils are found in the series above the commonly recognized upper limit of the Chemung series is very interesting.

Tioga River Section.—The following section of northward dipping rocks, made in the west bank of the Tioga river, a little below the mouth of Lamb's creek, and about three miles north of Mansfield, is also interesting as showing the occurrence of *Chemung fossils at a higher level in Catskill strata* than they have been supposed to exist:

Tioga River, Lamb's Cr. Section; Catskill

1.	Red shale (on top)	?
2.	Gray sandstone, with *Spirifer disjuncta*	6′
3.	Red shale	9′
4.	Gray sandstone	8′
5.	*Calcareous* and sandy layers, containing small *Lamellibranchiates* and *Rhynchonella*	4′
6.	Gray shale	1′
7.	Hard *calcareous* rock	2′
8.	Concealed	15′
9.	Gray sandstone	2′
10.	Red shale	3′
11.	Concealed	12′
12.	Red shale	6
13.	Concealed—estimated at	30′
14.	Red shale and sandstone, containing a *Lingula*	20′
15.	Greenish gray shale, containing a *Rhynchonella*	5′
16.	Gray sandstone, *Grammysia elliptica*	6′
17.	Gray and bluish shale	5′
18.	Red shale, four feet exposed	4′
	Total thickness of section	138′

No. 14 contains a bed of red shale four to six feet thick, which has been taken for iron ore and excavations have been made into it under the influence of this belief.

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terus. The surface of these scales was probably once highly polished, but like the fish remains of the Catskill, the organic tissue seems somewhat corroded.

"It is a singular fact, that while previous to last year, [1874,] no teeth of Dipterians had been found in this country, both *Ctenodus* and *Dipterus* were almost simultaneously discovered; one in the Coal measures of Ohio, the other in the Catskill of Pennsylvania."

Fossil Limestone of IX.—A few rods below this spot, behind an island and close down to the water, near the site of an old mill, a stratum of calcareous rock is exposed, two or three feet thick, containing traces of fossil shells. It probably overlies all the beds of the last section.

Catskill rocks may be seen at numerous other localities; as, in the Tioga river narrows, midway between Fralic's and Hickson's mills; at the Mill Creek bridge; at Brace's mill, on Mill creek, where it contains a thin seam of *coaly* matter.

In my study of the Catskill rocks of the Mill creek basin I have encountered the same difficulty, namely, that the rocks possess the *physical character* of the Catskill group in its typical locality the Catskill mountains; *but contain fossils* belonging to the Chemung group. This difficulty seems to increase going west, so as to involve the Upper Catskill also in Potter and M'Kean counties.

It looks as if the Chemung, Catskill and Vespertine, both in their lithological characters and in the number of fossils contained, undergo a marked transformation in their extension from east to west. As we recede from the sand bar deposits of the eastern border we shall see, in the shale and calcareous beds charged with organic remains, the evidences of deeper and more tranquil seas. This change is gradual, affecting the lowest beds first, but by degrees extending to the highest sub-carboniferous strata towards the western part of the State. In my judgment, the line which marks this change constantly runs higher, from one stratum to another, as we proceed to the west, though not at a uniform rate of ascent.

CHAPTER IX.

COWANESQUE ANTICLINAL.

The Valley of the Cowanesque creek lies between the Mill Creek mountain basin on the south, and the Cowanesque mountain basin on the north, and extends for about twenty-five miles from the Potter county line to the Tioga river. Its breadth varies from six miles at its western to ten miles at its eastern end.

The anticlinal axis which runs through it lengthwise crosses the west (county) line of Clymer township two to three miles south of the north-west corner; passes under Sabinsville, and a little to the north of Little Marsh P. O., to the north-west corner of Tioga township; the Tioga river at or near Somer's lane; thence to the north-east corner of the county. It continues its course in the same direction through Chemung county, N. Y.

The south edge of the actual valley is very nearly the line which separates the Catskill red from the Vespertine or Catskill gray rocks, as shown upon the map, and may be said to run from the forks of Long Run in Clymer, past Keeneyville and Tioga, to the south-east corner of Jackson township.

The northern edge of the valley is the south foot of the Cowanesque mountain, rising directly from the north bank of the Cowanesque creek as far as Elkland.

The valley includes more than half of Clymer, a small part of Westfield, nearly all of Chatham, the whole of Farmington and a part of Middlebury townships. The surface is made up of low, rounded hills; the soil is good, and adapted to grain and stock raising.

The drainage of the valley is complicated. The south branches of Cowanesque Creek (Potter's brook along the county line, Mill Creek through Sabinsville, the Jamieson, &c.,) drain its west end, northward; while the heads of Long Run (and Waddle's branch) drain the south dipping country, south-

ward, into Pine Creek. In the middle region, while other small streams flow north into the Cowanesque, the head branches of Crooked Creek drain from the axis at Little Marsh and Shortsville, southward, into the mountain. The eastern end of the valley is drained by the Elkhorn east south-eastward into the Tioga at Tioga village; by Mutton Lane and Somer's Lane Crecks also into the Tioga; while Cowanesque Creek crosses diagonally the valley from Elkland to Lawrenceburg, to empty its abundant waters into the Tioga.

The prolongation of the valley east of the Tioga River is drained westward by Mitchell's Creek south of the axis, and by several brooks north of it, into Tioga River; while Seeley's Creek head waters, Hammond's Cr., Adder Branch, &c. drain into New York State out at the north-east corner of the county.

Tioga River in issuing from the synclinal makes numerous bends up the dip, and trends away east of north in order to get through the anticlinal, after which it resumes its north course straight down the dip into New York. This conduct of the river is a curious repetition of its behavior after leaving the Blossburg synclinal to cross the Mansfield anticlinal.

It is very remarkable that Pine Creek, flowing in the opposite direction (southward) deflects towards the west in its approaches to the anticlinals, as the Tioga deflects to the east going north.

The central surface belt of gray, fossiliferous, Upper Chemung rocks is $3\frac{1}{2}$ miles wide at the west line, and 8 miles wide across from Elkland. They are exposed for 5 miles along the river below Tioga, to the State Line, and the belt continues 5 miles wide into Bradford county.

The red color on the map will show how the Lower Catskills border the Cowanesque banks as far as Elkland, and soon come to an end, leaving all the southern country of New York State with a rolling surface of Chemung.

The southerly dip may be seen in Clymer township, on Waddle's branch of Long run, between M. W. Newton's and L. Blue's; in Tioga and Farmington townships, along Elkhorn creek; along the Tioga railroad, opposite the village of Tioga; and at many other places south of the axis.

The northerly dip may be well seen in Westfield township; on Mill creek and the Jamieson; in Lawrence township, along the Cowanesque, above Lawrenceville, and elsewhere. The angle of inclination is extremely gentle, but perceptibly increases as we approach the mountains, and is somewhat stronger to the south than to the north of the central anticlinal.

Exposures of VIII and IX.—The best are on Waddle's brook, in Clymer township, where portions of both the Chemung and Catskill are visible; on Elkhorn creek, in Tioga and Farmington townships, where the upper part of the Chemung appears; along the Tioga railroads, opposite Tioga, where a very fine section of Chemung rocks can be got, and in a cutting of the Cowanesque railroad, two miles west of Lawrencetown, on lands of Thomas Knapp, where over a hundred feet of Chemung strata are exposed.

The Chemung rocks, it may be said in general terms, repeat themselves along this Cowanesque valley under the same aspect as along the Wellsborough and Mansfield valley, excepting that there are *more gray* and *fewer bluish and greenish* beds, especially towards the bottom of the visible mass.

I have little doubt that beds which further south I have placed in the Catskill have here become a part of the Chemung.

Such rocks form, then, the surface over the northern two-thirds of Clymer; the south-eastern third of Westfield; all Chatham, except a narrow border on the south, and and another at the north-west corner; a part of Deerfield, comprising the south-east corner; the valley of Holden Brook, and the valley of the Cowanesque as far up as the mouth of Troop's creek; all Elkland and Osceola, except a narrow border along the State line; all Nelson, Farmington and Lawrence; the north-west third of Middlebury and Tioga; and all Jackson, except a border on the south.

And in Bradford county:—all Wells township, except a few ridges capped with red shale in the vicinity of Old Hickory Post Office.

Waddell's Brook Section of VIII and IX.—This fine exposure in Clymer township, near the Potter county line, is especially valuable for showing the junction of the Chemung and Catskill groups. Specimens illustrating the physical characters of each

bed were collected for the museum of the Survey. The section begins at the top with the red Catskill beds, and passes down into the Chemung, the dip being pretty rapid southward

Waddell's Brook Section; IX, VIII.

1.	Gray shale and sandstone, with *Rhynchonella* and other *shells*	30′
2.	RED SHALE [characteristic of Catskill]	3′
3.	Gray shale and *calcareous* rock in thin bands, with two species of *fossil shells*	9′
4.	RED SHALE, with poorly preserved *fossil shells*	1′
5.	Gray sandstone	1′
6.	RED SHALE	4′
7.	Gray shale and shaly rock, gray sandstone and *calcareous* rock with *fossil shells* at intervals. This is at Mr. Blue's	100′
8.	RED SHALE	8′
9.	Gray sandstone	4′
10.	RED SHALE	10′
11.	Gray sandstone, shale and *calcareous* rock	75′
12.	RED SHALE and shaly rock	15′
13.	Concealed	25
14.	Gray sandstone	2′
15.	Concealed	10
16.	Gray shale and shaly rock	10′
17.	Mottled or variegated shale (red and green)	2′
18.	RED SANDSTONE	1′
19.	RED SHALE (*lowest of the red beds*)	3′
20.	Soft gray and bluish shale, with fragments of *iron ore* in the creek	65′
21.	*Calcareous* rock, with *fossil shells*	2′
22.	Gray, thin-bedded sandstone	5
23.	Soft gray shale	15′
24.	Gray, thin-bedded sandstone	8′
25.	Soft gray shale	4′
26.	*Calcareous* rock, with *fossil shells*	4′
27.	Soft gray and bluish shale	20′
28.	*Calcareous* rock in thin bands, with *fossil shells*	4′
29.	Soft gray shale	10′
30.	Gray sandstone and *calcareous* rock, with *fossil shells*,	5′
31.	Concealed	30′
32.	*Calcareous* rock, with *fossil shells*	3
33.	Gray, thick-bedded sandstone	8′
	Total measured thickness of section	496′

This section is between the farms of M. W. Newton and J. Davis. Chemung fossils of well known species can be found in nearly every bed of it; but they are not always well preserved in the upper beds. I have no doubt that all the beds above No. 20 would be found to be non-fossiliferous at a dis-

tance of less than forty miles towards the south-east; and that the red beds would be found to have increased in number and thickness, if they could be continuously traced.

The iron ore mentioned above as occurring in fragments in the bed of Waddle's Brook, was found to hold, on analysis, not more than between 18 and 19 per cent of iron.

Iron ore is said to show in a bed on Long Run, in Clymer township, in the hill above the road west of D. Jackson's, sixteen inches (at least) being in sight. This is given on the authority of Mr. Henry Baker. The specimens shown me were similar to the Mansfield ore, and the geological horizon would be about the same.

Elkhorn Exposures.—In Tioga township, on Elkhorn creek, Upper Chemung strata are well exposed, dipping pretty rapidly to the south south-east. They are chiefly gray (with some bluish) sandstones, shales, and calcareous layers It was at this locality that I once discovered the tooth of a new species of ganoid fish named by Dr. Newberry, *Heliodus Lesleyi.**

*The following description of this specimen is by Prof. J. S. Newberry, in the second volume of the geology of Ohio, 1875, Part II, Palæontology, p. 64:—

"Upper dental plate rounded or hippocrepi form, 1½ inches in length and breadth; triturating surface more than a half circle, highest in the centre, where it forms a broad smooth boss; from this radiate eight tuberculated ridges, four on either side of the median line, which is marked by a deep and smooth furrow. The ridges on each side differ among themselves, but are symmetrical with those on the other side, the lateral ridges being shortest, and bearing several tubercles, while the pair which borders the central furrow have but a single tubercle at the extremity of each. On both sides of the central boss the crown of the tooth is worn in a shallow rounded depression by the opposing teeth of the lower jaw. The posterior margin of the crown is nearly straight, and is slightly crenulated at the centre. This is bordered by a sloping surface which extends downward and backward about four lines, and expands laterally to form low, wing-like projections. This portion of the tooth was doubtless covered with integument."

In the description of Heliodus as a new genus based upon this specimen Dr. Newberry says:

"There is little doubt that we have in *Heliodus*, a new member of the family of Dipterine Ganoids to which *Dipterus*, *Ctenodus* and *Ceratodus* belong, and its dental plates present a sample but hitherto unknown modification of the characteristic dentition of the group. In the other genera of the family the palate teeth vary much in form and in the number and character of their radiating ridges. In *Dipterus*, the upper teeth have the form of right angled triangles, or half opened fans, the ridges being set with rounded and generally obtuse tubercles. The lower teeth are longer, like a fan two-thirds opened. In *Ctenodus* the number and form of the teeth is the same as in

Tioga Section.—Along the Tioga railroad, opposite Tioga, is one of the finest exposures of Upper Chemung strata to be found in the county. The following description of its layers in detail may be taken as a type of the exposures of Chemung in Northern Tioga:

Tioga Section; Chemung, VIII.

1.	Gray shale	8′
2.	Shale and *calcareous* rocks, with *Spirifers*	8′
3.	Gray thin-bedded sandstone, with carbonized stems of *plants*	6′
4.	Gray shale	3′
5.	Concealed	35′
6.	Gray shale	7′
7.	Concealed	100′
8.	*Calcareous* and sandy beds, with fossil *shells*	30′
9.	Concealed	72′
10.	Gray shale	20′
11.	*Calcareous* rocks, with shell (*Strophodonta*); leaves (*Lycopodites?*); and *fish* remains	3′
12.	Gray shaly sandstone	6′
13.	Reddish rock, with a considerable percentage of iron, (Place of the second Mansfield ore bed?)	1
14.	Gray shaly sandstone	24′
15.	Concealed	18′
16.	Gray sandstone and sandy shale	15
17.	*Calcareous* rock, with fossil *shells*	3′
18.	Gray sandstone and sandy shale	7′
19.	Concealed	6
20.	Thin *calcareous* bands with fossil *shells*, alternating with thin bands of gray sandstone and shale	44′
21.	*Calcareous* rock, with fossil *shells*	2′
22.	Gray thin-bedded sandstone	6′
23.	Gray rubbly shale, with thin sandy layers	38
24.	Gray sandstone, with concretionary masses and *calcareous* rock with fossil *shells*	35′
25.	Gray shale	14′
26.	Sandy and calcareous rock, with fossil *shells*	7′

Dipterus, but the radiating ridges are generally more compressed, and the tubercles are more acute. In *Ceratodus* the teeth are smooth, the ridges few and large, and without tubercles. Finally, in *Heliodus* we have the upper pair of palate teeth firmly joined in one plate, taking the form of a fully opened fan, and bearing radiating tuberculated ridges like those of Dipterus."

Dr. Newberry gives as his reason for concluding that these fish were gigantic Gar Pike, (to speak popularly,) and not Sharks, the fact that the remains thus found are composed, throughout, of true bone, and bear a fan shaped series of ridges, crowned with little knobs of tubercles, the summit of which are coated with enamel. No such structure as this is known to exist in any Elasmobranch fish, their jaws being cartilaginous, and their teeth attached to the jaw by ligaments.

27.	Concealed	6′
28.	Gray shaly sandstone and gray sandy shale	62′
29.	Gray sandy shale, with thin bands of *calcareous* rock in the lower half, containing fossil *shells*	70′
30.	Soft gray shale	3′
21.	Shale and, *calcareous* rock, with *Loxonema*, *Bellerophon*, and numerous *Lamellibranchiates*	3′
32.	Soft gray shale	4′
33.	*Calcareous* rock, with fossil *shells*	1′
34.	Reddish shale and sandstone	8′
35.	*Calcareous* rock, with fossil *shells*	1′
36.	Reddish thin-bedded sandstone	4′
37.	Concretionary rock	7′
38.	Gray shale and sandstone	8′
39.	*Calcareous* rock, with fossil *shells*	1′
40.	Gray shale and sandstone	9′
41.	*Calcareous* rock, with fossil *shells*	2′
42.	Gray sandstone	4′
43.	*Calcareous* rock, with fossil *shells*	3′
44.	Reddish shaly sandstone	3′
45.	Concretionary rock	4′
46.	Gray sandstone	4′
47.	Gray shale and sandstone	4′
48.	Soft gray shale	10′
49.	Concealed	25′
50.	Gray thin-bedded sandstone, at a bridge	20′
	Total thickness of measures	784′

This section extends along the railroad for a distance of a mile and a half, and its great thickness is owing to the uniform and comparatively rapid south south-east dip.

No. 1, the highest bed named, is anywhere from twenty-five to one hundred feet below the bottom of the Catskill formation. Yet it will be noticed that towards the bottom of the series some of the beds have a reddish cast.

No. 11 yields shells, fish remains, and the fern-like leaf of some land plant of the period, (*Lycopodites Vanuxemi?*) Its lower beds contain specimens of *Strophodonta perplana*, and *S. Cayuta*—shells which I have never seen south of the Mill Creek synclinal, though they are very common between this place and Corning, on the north.

Cowanesque Section.—The following section was made on lands of Thomas Knapp, two miles west of Lawrenceville, beginning in a cutting of the Cowanesque railroad and extending up the hill to the north. Farther to the north, at the State line, and probably five hundred feet higher, on lands of Jacob Zahn, the

surface is strewn with boulders and masses of coarse sandstone, weathering whitish. Their horizon is near the top of the Chemung. The dip of the strata in this section is to the north north-west:

Cowanesque R. R. Section, Chemung.

1.	Gray sandstone and *calcareous* rock, with fossil *shells*,	36′
2.	Concealed	7′
3.	Gray sandstone, one layer containing a peculiar fossil plant, something like a *Dictyophyton*	8′
4.	*Calcareous* rock, with *Spirifers*	2′
5.	Concealed	18′
6.	Gray shaly sandstone and flagging stone	15′
7.	Concealed	5′
8.	Soft light gray shale	8′
9.	Concealed	30′
10.	Bluish sandstone	5′
11.	Gray thin-bedded sandstone	4′
12.	Gray sandy shale	6′
13.	Concealed	7′
14.	Bluish-gray shale and shaly sandstone	8′
15.	*Calcareous* rock, with *Spirifers*, a species of *Fenestella*, etc.	2′
16.	Gray sandy shale, with concretions	9′
17.	Gray sandstone	8′
18.	Gray sandy shale	5′
19.	Gray flaky sandstone, with *Pterinea*	5′
20.	Gray shale	7′
21.	Bluish gray sandstone, with *Pterinea*	12′
		207′

Chemung Conglomerate?—At Mitchell's Steam Mill, on the head of Alder run, and elsewhere in Jackson township, there are large quantities of sandstone boulders, mostly a coarse, gritty rock, weathering white. They cover the ground in many places, and some of them are large, but contain no fossils. The horizon from which they were derived appears to be about two-thirds of the way up the hill, in the Upper Chemung. They look like the rock on Fall creek, in Ridgebury township, Bradford county. The only strata observed in place was a peculiar shale or slate, having a rusty appearance on the surface, and lying not far below the bed from which the boulders came.

Dictyophyton.—Back of the Methodist church at this place we found two specimens of *Dictyophyton tuberosum*, lying on the surface. They are like those at Bath, N. Y., and the place is somewhat similar.

CHAPTER X.

COWANESQUE MOUNTAIN BASIN.

The Cowanesque mountain basin lies next north of the valley last described ; and its southern boundary has been described in the last chapter. Its northern wall, overlooking Southern New York, runs through the middle of Brookfield township and the north-west corner of Deerfield, in a line N. 60° E.

It can hardly be called a continuous mountain. It is rather a chain of isolated high hills of Catskill rocks separated by the five principal northern branches of the Cowanesque Creek. The patches of Vespertine or Upper Catskill (X) forming the summits are small and lie upon a broad base of Lower Catskill (IX) about 4 mile wide, as shown by the red color on the map, and terminating in New York State a few miles north of the State line. In fact Norway Ridge, which lies between Camp Creek and Holden Brook, Woodhull township, Steuben county, is the last and most north-easterly of the high, barren hills, whose summits are capped with Vespertine rocks ; and I believe that it is the only locality in the State of New York, west of the Catskill mountains proper, where rocks of this same Upper Catskill age exist.

The centre line or synclinal axis of the basin enters Tioga county exactly at the north-west corner, and passes out exactly at the north-east corner of Deerfield.

In its prolongation north-eastward it crosses the Tioga river near Lindley, and runs on midway between Elmira and Horseheads.

All the summits of the range are of about equal height and rise several hundred feet above the country on each side.

The streams dividing the range all head in New York State and flow into the Cowanesque, viz: Potter Brook, the North Fork, Troop's Creek, Holden Brook and Camp Creek. The Cowanesque ploughs a deep furrow-like valley through the body of the mountain, parallel to and a mile or so south of the synclinal axis, from where it enters the county to Elkland. Even where the Chemung rocks appear in the valley of the creek, the red Catskill rocks form the hills on its southern side.

Along the central belt, one or two miles wide, the Lower Red Catskill is covered with the Vespertine gray (Upper Catskill) rocks, much reduced in thickness, and perhaps nowhere retaining on them a residue of the Umbral red shale, Seral conglomerate, or Coal measures, which undoubtedly once covered the country.

North dips may be noticed on Potter brook, Mill creek, and at various points along the Cowanesque; above Knoxville, near Elkland; and above Lawrenceville, and on Tioga river.

South dips may be seen on the north fork, about two miles above its mouth, where the road crosses the creek; along Troop's creek, three or four miles above its mouth, and at the head of Holden brook.

Exposures.—Owing to greater accumulations of *detritus*, the rocks are generally not so well exposed in this basin as in those already described farther south.

Lower Catskill (IX) may be seen in the banks and bed of the Cowanesque, a little above Knoxville; on Troop's creek, at the Knoxville bridge; and at a quarry a short distance above.

Upper Catskill (X) may be seen jutting from the brow of the mountains in many places on the north side of the Cowanesque.*

The Catskill rocks of the Cowanesque basin vary but little from those of the Mill Creek basin, except that the thickness is not so great. There appears, also, to be more sandstone and less shale, more gray and less red, and more beds with fossil shells.

The belt of red rocks south of the synclinal axis, running through the central part of Westfield and Deerfield, the north-

* I am unable to affirm positively whether or not any strata higher in the series than this occur on these mountains.

west corner of Chatham, and the north edge of Osceola and Elkland townships, is connected with the belt of red rocks on the north, running through the Central part of Brookfield and the north edge of Deerfield, into the State of New York, through the valleys of all the larger creeks coming into the Cowanesque from the north; for the dips are so exceedingly gentle that they nowhere carry these rocks below the beds of the streams.

The red rocks cap the hills in the south part of Steuben county, New York, but do not appear to reach as far east as the Tioga river.

Exposures are numerous, but generally not of much extent, and I have found none of special interest.

Notes.—The thinning away of the Red Catskill formation (IX) in a direction towards the north-west is a marked feature of the district, and was illustrated in the survey of 1841 by diagrams, two of which appear on pages 310 and 312 of Prof. Rogers' final report of 1858. These are re-produced in Fig. 4, and placed face to face to make the facts more evident to the eye. One was made up the side of the Blossburg mountain, east of the Tioga river; the other up the south flank of the Crooked Creek mountain a few miles *north* (not *south*, as the legend to fig. 44, F. R. 1858, Vol. I, p. 312, makes it) of Wellsborough.

These sections were made at points not more than fifteen miles apart, and yet the Red Catskill (IX) has diminished in thickness to one-third; as is proven by the presence in both sections of the limestones in their regular place near the base of the Upper Gray Catskill (X.)

This *Vespertine Limestone* is fossiliferous, and overlies a bed of bluish sandstone, eight to ten feet thick. It shows itself in large blocks in the railroad cuttings three miles below Blossburg, where the dip of the mother rock is from 6° to 8° S. S.E.

In the Cowanesque mountain the Upper Gray Catskill (X) is very much reduced in thickness, and the Lower Red (IX) still more.

At Knoxville the north dip of the Chemung rocks in the creek is 2°.

On Troup's creek, a half mile above its mouth, at the saw mill, where thirty feet of red shale appears, containing so much iron that ore bogs are formed by the springs which issue from the foot of the hill, the first overlying 200 feet of rocks in the mountain side are of green *Chemung* sandstone, as shown by the characteristic pink soil, and the fragments covering the surface.

Above this, on the slope, are seen *in place* the thin-bedded, *Upper Catskill* sandstones, showing the characteristic false bedding and pitting of the fractured surfaces with black specks. This is a very interesting feature of X when considered in connection with the discovery of small coal beds in this formation in other counties of the State.

Near Knoxville the thickness of X would be 500 feet if measured up to the heavy outcrop of white sandstone, (XII?) since there is no appearance here of the red shales of XI, (although its ore appears eight miles further west,) nor much appearance of any true red rocks of IX.

The Mansfield ore (and red shale) was recognized in 1841 on one of the high hills eight miles south-east of Knoxville and nearly on the anticlinal axis, on the road to the forks of Crooked creek. No limestone was seen there. At Knoxville the limestone must underlie the surface at no great distance; as it was opened on the Cowanesque creek, two miles below Knoxville, showing two feet of poor, fossiliferous limestone.

If this be the Mansfield Chemung ore, red shale and limestone, and not Red Catskill, then the Lower Red Catskill has thinned away to nothing, or has entirely changed its character.

Note, on the Extension of the Anticlinals and Synclinals through the State of New York, towards Albany.

The connection between the synclinals and anticlinals which are observed crossing the Delaware river, with the synclinals

of Carbondale and Tunkhannock, and the Harvey's Lake and Wilmot anticlinals cannot be doubted, although they have not yet been carefully traced from the Delaware to the Susquehanna rivers. The proof is afforded by the geological map of the State, (1858) in the sweep of the Wilkesbarre, Scranton and Carbondale coal basin upward to the north-east, and the parallel sweep of the Tunkhannock Creek mountains.

No attempt has been made in the progress of the survey of Tioga and Bradford counties to follow the Wilmot and Towanda anticlinals through Susquehanna county. This must be left for another season. But to show that these great waves are not confined to Pennsylvania, it is well to name certain localities in New York State where the Tioga county waves have been followed and noticed.*

The Crooked Creek (Mill Creek) synclinal axis crosses the Chemung River between Wellsburg and Chemung, from whence it runs past Owego on the north to Chenango Forks, on the Chenango, and thence through Rockdale on the Unadilla, to West Oneonta and beyond. Evidence of this is seen in the north-westerly dips mentioned above, in connection with the Mansfield and Wellsboro' axis, and the south-easterly dips on the Chemung, below the mouth of Seeley Creek; at Newark Valley, on Owego Creek; at Oxford, on the Chenango; and Mount Upton, on the Unadilla.

The Sabinsville anticlinal axis leaves Pennsylvania and enters New York where Tioga, (Pa.,) Bradford, (Pa.,) Steuben, (N. Y.,) and Chemung, (N. Y.,) counties corner on each other, It crosses the Chemung River a little below Elmira; the West Branch of the Chenango between Lisle and Whitney's Point, and the East Branch at Norwich, as is clearly shown by the north-westerly dips at Lawrenceville, Elmira, Upper Lisle, etc.; and by the south-easterly dips referred to above in connection with the Mill Creek axis.

The Cowanesque synclinal crosses the Tioga River a little below Lindleytown; the Chemung River below Big Flats; passing midway between Elmira and Horseheads; and crossing the West Branch of the Chenango (Tioughnioga) at Marathon,

*By Mr. Sherwood, under the direction of Prof. Jas. Hall, previous to 1875.

from whence it probably extends into Chenango county. The only evidences in my possession, however, which would tend to show that it extends beyond Chemung county are the topographical features of the country in that direction, and the finding here and there* of a conglomerate, which occurs in the Upper Chemung at intervals over Southern New York and Northern Pennsylvania. I have seen no dips beyond Elmira and Horseheads. At the first of these two places it is northwesterly ; at the latter south-easterly.

*As south of Pharsalia and east of Cincinnatus, Chenango County, New York.

PART II.

COAL BASINS OF BRADFORD AND TIOGA COUNTIES, AND AT THE FORKS OF PINE CREEK IN POTTER COUNTY.

CHAPTER XI.

The Barclay Coal Basin in Bradford County.

The Barclay Coal Basin of Bradford County is a moderate area, included in Barclay and Leroy Townships.

The report of Mr. Sherwood, pp. 1–96 of this volume, and the colored geological map which accompanies this Report, define clearly the limits of the Lower Productive Coal Measures in Bradford County, and explain why they are caught in no one of the synclinals save only in this Barclay basin.

Topographically and geologically the basin is well defined.

To the north of it the Towanda Mountain makes a straight and continuous wall, over 2000 feet high above the level of the sea, though really but little above the level of the table land made by the Coal measures in the centre of the basin.

On its north face the Towanda Mountain falls off abruptly, and the measures of XI and X, clearly defined on this north escarpment, make a pretty rim along that side.

Drainage of the Basin.

The Schroeder Creek heads in Leroy Township, Bradford County, in Fox Township, Sullivan County, and in McIntyre Township, Lycoming County.

These forks unite, and the Creek flows to the N. E., keeping parallel with and south of Towanda Mountain, and distant about 2½ miles from it.

Where the Towanda Mountain points out at Greenwood, in Monroe Township, the Schroeder Creek curves northward around its point and joins Towanda Creek.

Limits of the Basin.

The Schroeder Creek is the practical south line of the Lower Productive Coal Measures in the Barclay Coal Basin. There is indeed apparently a small area of Coal Bed B on the south side of the Schroeder Creek, near the extreme east end of the basin, but it embraces only a few acres, and is as yet but little explored.

Considering the basin as a whole, it may therefore be said that for all purposes of working Coal bed B, the basin is north of the Schroeder Creek.

All of the features above described are plainly shown on the Bradford County Map accompanying this report.

The outline of the area of coal bed B is laid on the map, solid in color where it is clearly defined and worked on the north side of Schroeder Creek, and with a dotted line around it on the south side to indicate the less certain character of that work; but it will be noted that there are no outcrop limits to Coal bed A.

As this bed lies regularly 60 to 80 feet below bed B, its line of outcrop could easily be laid on along the Schroeder; but on the north side of the basin its outcrop is concealed on a broad flat, where a slight change in dip would make a great difference in increasing or diminishing the acreage covered by the bed.

For this reason the Measures are thus sub-divided:

1. Conglomerate of XII, Bed A, and Measures up to Bed B.

2. Coal Bed B and overlying rocks.

Moreover there is reason to believe that Coal bed A is caught in various hill tops west of Sunfish Lake and south of the centre line of the basin.

But in view of the fact that this bed is in the Barclay region as a small though regular bed, not averaging 2 feet in thickness, though in places running up to 3 feet, it was not deemed necessary to examine into and plot every acre where it may have caught in the hills. The country is heavily wooded and only a slow and thorough survey, by a completely organized party and with all needful instrumentation, could locate closely the detached areas.

Many years hence, when bed B is exhausted from the basin, Coal bed A will become valuable, and a thorough examination of its outcrop line will be necessary ; but at present the bed A is of but minor importance, and is nowhere mined in any part of the region.

Outlet for the Coal.

The great value of the Barclay Coal Basin lies in its proximity to its market as well as in the excellent character of the coal as a steam raising fuel. A comparatively short distance places the coal on the line of the New York and Erie R. R. at Waverly ; and 82 miles further puts it upon the New York Central R. R. at Geneva.

Both of these roads for their own use need great supplies of fuel ; and at present all of the product of the Barclay Mines goes to the New York & Erie R. R., and a large part of the Schroeder Mine coal to the New York Central R. R.

The distances are—

Barclay to Towanda, ... 16 miles

Towanda to Sayre, via the Penna. & N. Y. Canal and R. R. Co., ... 21 miles

Sayre is on the N. Y. and Erie Railway.

From Sayre to Geneva, ... 82 miles

Geneva is on the New York Central Railroad.

The acreage of Coal bed B in the Barclay basin is shown on the map accompanying this report. Only a part of this

acreage has been mined out; and the basin will continue to yield at its present rate for many years from bed B alone.

When this is exhausted Coal bed A can be attacked at points where it reaches $2\frac{1}{2}$ to 3 feet of good coal; and as the acreage is much more extensive than that of bed B it will undoubtedly continue to supply coal for a great number of years.

The discussion of the axes bounding the Bradford County Coal basin as well as the Tioga County basins, will be given after the details of the Tioga Coals, when there will be also given all discussions of character of coals, usefulness for specific purposes, &c., as well as relationship to the Lower Productive group of coals as showing in the first, second, and third basins in Clearfield, Cambria, Indiana, and Somerset Counties.

Detailed Report.

The Barclay Coal Basin is a part of a tract of 30,000 acres purchased in 1794 by Robert Barclay, of London, England.

The existence of coal in the region was known at an early date, and some coal was mined soon after the settlement of the county. It continued to be mined thereafter on a small scale and was hauled away in wagons to supply blacksmiths in Northern Pennsylvania and Southern New York.

No geological examination of the region was made until the year 1835 when R. C. Taylor reported upon it. Since then it has been thoroughly developed and opened, and the record of the numerous trial pits and drifts is found in the reports made by Walter R. Johnson (1840) and J. P. Lesley (1853).

These reports covered the whole basin, and made an exhaustive description of the limits of the basin, the area of the different coal beds, and their size, character and accessibility to market. The trial openings are long since closed and cannot now be examined.

Inasmuch as only a small portion of the Barclay region is as yet worked out, these facts of Professors Johnson and Lesley are of as much importance as ever in enabling a

judgment to be formed of the structure, area, and future yield of the basin. These reports therefore will be freely drawn upon for such facts as are not now accessible without special opening for the purpose, and to these facts will be added the observations made during the State Geological Examination of the basin in 1877.

It is not necessary to reproduce any facts from the report of R. C. Taylor made in 1835. It was simply a preliminary report, made without much opening up of the outcrops; it reported generally the existence of a coal basin, holding coal beds A and B; and that the basin was of sufficient area to justify its complete development and the expenditure of the money necessary to provide an outlet to market.

Report of Prof. W. R. Johnson.

Five years later (in 1840) Prof. Walter R. Johnson, with an efficient corps of assistants, and abundant time and means, made an examination of the region, defining somewhat generally the outcrop lines of the coal beds, opening up and examining the coal benches at numerous points, defining the size and character of Coal beds A and B, as well as the iron ore deposits, and finally locating a railroad line down Schroeder Creek to afford an outlet to the Susquehanna River.

Johnson's statement of facts can best be given in his own order and in his own words.

"The most important portion of the Coal of this formation appears to be included in two principal beds, known as the upper or "big vein" and the lower or "three feet vein." The upper bed has been exposed in six or seven different places, and has an average elevation of 1219 feet above the level of Towanda.

The lower bed, where exposed, not far from the head of Fall Creek, is at an elevation of 1112 feet, but to the southwestward of this point, the same bed is found at a higher elevation.

The lower bed, where opened, at the southeast side of Fall Creek, near its head, was measured, and gave the following vertical section, beginning at the top:

	Ft.	In.
1. Sandstone, about,	30	
2. Slate and Iron-shale,	2	
3. First, or upper ply of *Coal*,		$12\frac{1}{2}$
4. First ply of Slate, intermediate,		5
5. Second ply of *Coal*,		2
6. Second ply of Slate,		4
7. Third ply of *Coal*,		$9\frac{1}{2}$
8. Third ply of Slate,		1
9. Fourth ply of *Coal*,		4
10. Fourth ply of Slate,		2
11. Fifth ply of *Coal*,		$5\frac{1}{2}$
12. Fifth ply of Slate,		6
Total *Coal*,		$33\frac{1}{2}$

The last ply of slate rests on a white gritstone, 5 feet in thickness, below which occurs a stratum of gray sandstone; and under that fireclay four feet thick.

The southwestern opening, which has been hitherto supposed to be on the same bed, has exhibited a more unmixed series of coal-seams, viz:

	Ft.	In.
1. Sandstone, as before, about,	30	
2. Top slate,	4	
3. Upper *Coal* Seam,		16
4. Upper Slate,		2
5. Second *Coal* Seam,		$15\frac{3}{4}$
6. Second Slate,		4
Total *Coal*,		$31\frac{3}{4}$

The coal in this drift is not only less separated into thin plies than the other opening, supposed to be on the same bed, but is of more uniform texture. The *mining ply* in this bed, is a stratum of four inches of soft slaty matter, two inches above the upper seam of coal, constituting part of the four feet of *top-slate.*

The next series of measurements which I made on the Coal beds, was near the old cabin, at the end of Miller's coal road, and in the eastern opening. The pit sunk at this point was too near the outcrop to enable me to decide with entire accuracy all the points in regard to either the the thickness or elevation of the seams. The gradual decaying and breaking down of the stratification on the slopes of the mountain, often render the measurements

taken at the surface of the ground uncertain; and the uncertainty is the greater as the materials below the coal are more perishable and easily washed away. The top of this bed appeared to be 1201.6 feet above our base line, and consequently, 89.6 feet above the level of the first opening above described, and 52.6 feet above the second.

The series was as follows:

	Ft.	In.
1. Covering of Sandstone, much broken,	4	
2. Iron-shale,	3	
3. *Coal*,		32
4. Slate,		15½
5. *Coal*,		8½
6. Slate,		1½
7. *Coal*,		13
8. Slate,		14
9. *Coal*,		29
Total *Coal*,		82½

The lower ply only of coal had here any degree of cohesion, owing to the nearness to the outcrop; but the distinctive character of each seam, both of coal and slate, could be readily discriminated.

The fourth opening, in which measurements were taken, was about 300 feet N. 56½° W. from the preceding, in what has been called Miller's Old Drift, near the cabin, at the end of the coal road. The roof of this opening is 1212.6 feet above our base line, and 10.9 feet above that of the preceding opening. Its covering is iron-shale, with some iron ore intermixed, above which is sand-rock as above described:

	In.
1. *Coal*,	32
2. Slate,	4
3. *Coal*,	19½
4. Slate,	7
5. *Coal*,	21
Total *Coal*,	72½

The above were all the strata exposed in this drift, in a manner to be easily approached or measured.

I had an opportunity of measuring the thickness of the bed on which Barclay's mines are opened, at a distance of

a little more than one and one-third miles, in a direct line, bearing South 81° West from the Old Drift just described. I then found the following section, viz:

Under a covering of sandstone is a roof of nine inches of slate, and then—

	In.
1. *Coal*,	35
2. Slate,	11
3. *Coal*,	6
4. Slate,	5
5. *Coal*,	20
6. Slate,	3
7. *Coal*,	6

Total *Coal*, 67 inches, of which 61 inches are worked.

The level of this bed does not lie more than 20 feet above that of the Old Drift near Miller's cabin.

It is a well-known fact, that where coal and slate seams alternate in the same bed, the relative thickness of the several plies of the two materials may vary very considerably within a few hundred yards. This may suffice to account for all the differences which have been observed on the superior bed of coal in this basin. It would not be safe, however, in a country so little explored, and so much in its primitive condition of a deep forest, to pronounce against the existence of more than two beds which I have laid down. These are certain, and their existence is sufficient to stamp a value on the region which it will require a long period to exhaust.

Analysis of Coal.

Eight samples of the coal of this region have been examined.

No. 1. This specimen is from the fifth ply of coal, in the lower bed, opened near the head of Fall Creek:

	Per cent.
At a temperature of 300°, it loses of moisture,	1.3
By distillation at a red heat, it loses of water,	4.5
Uncondensable gaseous matter,	9.2
It contains of Carbon,	62.6
And of earthy matter,	22.4
	100.0

The ashes are almost perfectly white, and of moderate density. This, as well as the two following specimens, are from parts of the bed so near the outcrop as to yield, as in all similar cases, a higher proportion of earthy matter than would be found to exist in the coal when not exposed to the decomposing influence of the atmosphere.

No. 2. This specimen was from the third ply of coal, in the same opening as the preceding.

The thickness of this ply is 9½ inches.

Its specific gravity is 1.4485.

	Per cent.
At 260°, it loses of moisture,	1.9
At a bright red heat, it gives of water,	6.2
At a bright red heat, it gives of gas,	9.3
It contains of carbon,	70.
And of earthy matter,	12.6
	100.0

The ashes are dense, and of a grayish white color.

No. 3. This sample is from the second ply of the same bed, the thickness of which is two inches.

	Per cent.
At 220°, it loses of moisture,	1.2
At redness, it is decomposed, giving of water,	5.7
At redness, it is decomposed, giving of gas,	12.2
It contains of carbon,	63.9
And of earthy matter,	17.0
	100.0

The ashes are light, and have a white color, slightly inclining to buff.

No. 4. This sample of coal was taken from the Old Drift of Miller's opening, northwest of the head of Fall Creek, and from the middle coal of that bed, which is 19½ inches thick. Its structure is somewhat irregular, inclining to rhombic, and its color rusty brown. The surfaces of deposition presenting distinct traces of vegetable fibres in a state of charcoal.

Its specific gravity is 1.3771.

	Per cent.
It loses in moisture at 220°,	2.5
At a red heat, it parts with water,	3.0
And of combustible and other gases,	15.0

It contains of earthy materials,	11.4
And of carbon,	68.1
	100.0

The ashes of this coal are almost perfectly white, or but very slightly inclining to buff.

No. 5. This specimen is from the lower part of the upper 32 inch ply of coal in Miller's Old Drift, and possesses a cubical structure, with a specific gravity of 1.3784.

	Per cent.
It possesses of hygrometric moisture,	1.0
Water given out in coking,	3.5
Gas volatilized by bright red heat,	14.7
Carbon,	65.5
Earthy impurity,	15.3
	100.0

The ashes are moderately light, and of a gray color, compounded of white and chocolate.

No. 6. This sample was likewise from the upper 32 inch ply of Coal in the Old Drift before mentioned. It possessed the cubical structure, and a fine, deep black color.

Specific gravity 1.3492.

	Per cent.
It contains of moisture vaporized at 212°,	1.3
Of water, tar, &c., disengaged in coking,	6.5
Uncondensable gas,	11.5
Carbon,	74.97
Earthy matter,	5.73
	100.00

The ashes are of a rather deep chocolate brown, scarcely less marked in this particular than any of the red ashes of Anthracite.

No. 7. This coal was obtained from the middle of the bed at Mason's Mine, on the head waters of Wagner's Run. The coal from this mine is already in the highest repute both for domestic consumption and for purposes of the arts.

It has a specific gravity of 1.388.

	Per cent.
Matter volatile at 390°,	0.6
Vapors condensable,	2.8
Uncondensable gaseous matter,	15.4
Carbon,	68.1
Earthy matter,	13.1
	100.0

The ashes of this coal are white, slightly inclining to buff, moderately bulky.

No. 8. This coal is from the lower part of Mason's bed. It possessed a columnar structure, the surfaces of deposition being distinctly marked; its color deep black; surface of vertical fractures shining.

Its specific gravity is 1,400.

	Per cent.
Water lost at 340°,	2.1
Volatile matter expelled in coking,	16.8
Carbon,	68.57
Earthy matter,	12.53
	100.00

The ashes of this Coal are of a white color, rather inclining to gray, and not remarkably heavy.

Experiments to detect the presence of sulphur succeeded in giving faint traces of that ingredient.

From all the analyses of the Coal detailed in this Report, we have the following table of general results: *

No.	Carbon.	Vol. Matter.	Earthy Matter.
One,	62.6	15.0	22.4
Two,	70.0	17.4	12.6
Three,	63.9	19.1	17.0
Four,	68.1	20.5	11.4
Five,	65.5	19.2	15.3
Six,	74.97	19.3	5.73
Seven,	69.00	17.9	13.1
Eight,	68.57	18.9	12.53
Mean,	67.83	18.41	13.76

Thus it appears that the quantity of volatile matter in this coal is small, compared with that of most other bi-

* Coals numbered 1, 2, and 3, are from *Coal bed A*. The average of the three analyses is:

Carbon.	Vol. Matter.	Earthy Matter.
65.5	17.17	17.33

Coals numbered 4, 5, 6, 7 and 8 are from *Coal bed B*. The average of the five analyses is:

Carbon.	Vol. Matter.	Earthy Matter.
69.23	19.16	11.61

tuminous coals of our country. Being situated on the eastern extremity of the first principal range of bituminous coal-formations west of the Susquehanna River, it adds another to the many evidences which have been derived from my own experiments, in proof of the position long since advanced, that the quantity of volatile matter in the coals of Pennsylvania, and other States, gradually increases as we advance from the Atlantic region, across and beyond the Alleghany Mountains, over the great coal fields of the Western and Northwestern States.

This law becomes the more striking when the Anthracite fields are embraced with the bituminous, for there we have a series commencing almost at Zero, and proceeding upwards in the scale of volatility, till in some of the coals of Kentucky, Illinois, &c., it attains a maximum of 48 or 50 per cent. The circumstance of possessing but a moderate share of bituminousness is favorable to the application of the coals of this region to the purposes of iron manufacture, and though the percentage of earthy matter is higher than that of some other coals, yet it will be recollected that nearly all the samples are taken from points near the outcrop of the respective beds, and that consequently the relative proportion of earthy matter is likely to be higher than would result from the coals taken a few hundred feet from the edge of the same beds.

Iron Ores.

The argillaceous carbonate of iron is the principal variety to be expected in all coal districts. The Carbon creek formation is found in this respect to sustain the general character of all our Pennsylvania coal fields, yielding ores in considerable variety, and of different degrees of richness, capable of producing from six or eight, to forty or fifty per cent. of metallic iron. These ores have been found either in place in the solid strata, or scattered in rolled pebbly masses, over so much of the property as to leave no doubt of their constituting, originally, regular portions of the formation. Thus I have collected samples from the heads of Fall Creek, and from those of Long Valley, as well as along

the *channel* of the latter tributary ; they are also met with in Wagner's Lick Creek, and especially on the heads of the latter stream, where the ore has been fully exposed a few hundred yards from Mason's coal mines. Kidney ore is found in several places directly overlying the upper bed of coal.

The lowest stratum of ore which I have been enabled to examine, is situated, as above mentioned, 1016 feet above the level of our base line, such at least is the elevation where opened on Fall Creek. It constitutes a bed $37\frac{1}{2}$ inches thick, reposing on a bed of fireclay, 16 inches thick, and covered with a ferruginous shale, 6 inches thick. From this statement, it will appear that the mining of this ore will be effected without any unusual difficulty.

In the solid part of the stratum, where the influences of the weather have not interfered with its natural state, it is of light blue color, of irregular texture, being sometimes uniform, and at others conglomerated of clay and fragmentary masses of iron ore. The weathered specimens are commonly of a dark brown color, approaching to black, and are obviously changed from the character of carbonates of the protoxide to hydrated peroxides of the metal. As in passing through this change some portions of earthy matter are commonly separated and washed away, the ore in this latter condition is richer than in its previous state of a carbonate, the *loss* in carbonic acid and earthy matter being greater than the *gain* in oxygen and water. This remark will also apply to the other carbonates, as compared with the hydrated parts of the balls or blocks of ore. In the process of decomposition the hydrate is often accumulated in the form of a shell, more or less regular upon the exterior of a nucleus of spongy earthy matter, nearly destitute of iron ; such shells are occasionally found in the bed now under consideration. The following are the results of my examination of this ore :

No. 1. A specimen of this ore from near the outcrop was selected, having the elongated kidney form, a shell enclosing white earthy matter, its color in recent fractures of the shell, dark brown.

Its specific gravity was 3.2264 at a temperature of 56° Fah. It lost at 320° 2½ per cent. of water; and by the application of a white heat for some time, the combined water expelled amounted to 21.1 per cent.

An assay of this ore in the dry way, without any admixture whatever, gave of metallic iron, 32.5 per cent., and of earthy cinder, 29.8 per cent.; oxygen, 14.1 per cent.; water, 23.6 per cent.; of which 2.5 per cent., as above stated, was uncombined.

This analysis proves that for each equivalent of iron, in combination, (28), there was present 1½ equivalent of oxygen (12) and 2 equivalents of water. This corresponds with the constitution of bihydrated peroxide of iron.

The pig metal obtained in this assay was of a light grey color, and rather brittle. This trial proves that the ore will not actually require the use of any flux for its reduction.

No. 2. This sample was taken from under the fall, below the lower bed of coal, and was in the original state of the mineral, not changed to hydrate as in the preceding example. Its color is light blue, its texture is amorphous, or foliated, its fracture irregular; some shining particles, probably pyritous, are distributed through it.

Its specific gravity is 3.0549. At 320° it loses 0.5 per cent. It loses when heated to whiteness, 10.5 per cent. of carbonic acid, with probably a little sulphur. The amount of iron contained in this ore was 24.2 per cent.; of earthy materials, 49.2. The state in which the iron exists in this ore is doubtless that of a proto-carbonate. The cinder was brittle, of a green color, and perfectly fused.

No. 3. This ore was taken from the fifth ply of a bed about 10 feet in thickness, and at an elevation of 1,080 feet above our base line, and 64 feet above the 37½ inch bed already described. The ply is 18 inches thick.

This ore has a brown or ochrey appearance, and being taken from a point at no great distance from the outcrop, has evidently undergone a change from atmospheric influences. Its fracture is uneven, and its texture analagous to some of the argillaceous shales. Its specific gravity is 2.7256. It contains of hygrometric moisture, vaporizable

at 320° Fah. 2 per cent.; of water in combination 4.8.; metallic iron 44 per cent.; earthy matter, 24.3.

The remaining 4 portions of the 10 feet bed, from which the preceding sample was taken, were examined and found to yield different quantities of iron, from 6 to 16 or 20 per cent. It is probably that in working some of the other varieties of ore found on the Company's domain, portions of this 10 feet bed will be found available as furnishing materials to promote the fusion and facilitate the working of the richer descriptions, which do not contain a sufficient quantity of earthy ingredients to produce a good cinder for the protection of the iron in the hearth.

No. 4. This sample is from a stratum of iron ore and fire clay found on Fall Creek, at an elevation of about 46¾ feet above the lower bed of coal, or 1,158 feet above our base line; the bed of materials in which it occurs is 2 feet 6 inches thick, of which 4 inches at the bottom are fire clay, the remaining portion iron shale, intermixed with flattened reniform masses of argillaceous carbonate of iron, and some carbonaceous matter derived from fossil vegetable remains. The whole bed, together with the superincumbent mass of sandstone rock, or fine conglomerate, appears to have fallen from place, and the situation was not therefore favorable for determining the real value of the bed. The sample submitted to experiment was a fair type of the ore in this bed; but it should be added, that all which we could conveniently obtain at this place had undergone a change, and been reduced from carbonate to hydrate. Its specific gravity was found to be 3.2113.

It lost of hygrometric moisture,	3.5 p. c.
Of combined water, expelled by a full red heat,	12.7 "
Pig metal,	53.4 "
Earthy matter,	5.8 "
Oxygen,	24.6 "
	100.0 "

The pig metal is of good quality, soft, gray and tough. The cinder was imperfectly fused, but with 20 per cent. of lime would probably be fully reduced.

In the assaying of other parts of this band of 10 feet of

argillaceous ore, a friable, semi-vitreous cinder was obtained by the use of one twentieth its weight of carbonate of lime; but the large quantity of earthy matter in the ore would demand in practice considerable increase of that quantity, probably to the extent above named.

No. 5. This ore was discovered on the head waters of Long Valley creek, in a decayed and broken down portion of the measures, in such a situation as induces me to believe that its original place in the formation is near the level of the lower bed of coal, probably a little above it. Its color is brown externally, and yellowish within; it is evidently a hydrate, formed by the decomposition of carbonate.

Its specific gravity is 3.3604.

It lost of water, by heating to 320°,	3.8 p. c.
And at a white heat,	14.1 "
Of pig iron, it gave,	48.4 "
Earthy material,	3.9 "

The pig metal was gray, tough, and moderately soft; the cinder opaque, grayish white. In this assay the cinder was rather imperfectly reduced, and some portions were probably lost.

No. 6. This specimen of ore was taken from a pit sunk about 8 feet deep, near Mason's coal mines, on the head waters of Wagner's Run; the band of flattened balls, very closely compacted together, is 6 inches. This band of ore is found near the north-easterly outcrop of the series of coal measures, a few feet only above the level of the heavy stratum of conglomerate rock which marks so distinctly the limit of the basin in that direction. In this same locality are exposed three other strata of ore, the first of which is $5\frac{1}{2}$ feet above the one now under consideration, the second $6\frac{2}{3}$ feet, and the third about $7\frac{1}{2}$ feet. This last is a band of balls, as will be more particularly stated below; hence it will be seen that all four of these bands of ore may be worked together within a vertical height of 8 feet. The total thickness of the four bands being about 18 or 19 inches, and the intervening matter to be mined out ferruginous slate and rather friable sandstone, will not, I apprehend, present any serious difficulties in the mining.

The following section shows the whole of these measures, commencing at the top:

	Ft.	In.
1. *Balls of iron ore*,	0	3
2. Slaty sandstone,	0	9
3. Upper *band* of *iron ore*,	0	6
4. Silicious iron shale,	1	0
5. Middle band of *Kidney ore*,	0	5
6. Ferruginous slate,	5	0
7. Lower band of compact *balls of iron ore*,	0	6
8. Iron shale,	1	6
9. Black slate,	0	6
10. Iron shale,	1	8

The four varieties of ore found at the above locality are also met with in various other situations on the property, especially on Long Valley creek, in the bed of which samples exactly similar to the lower band of the above section have been observed in numerous places. This band is of a durable texture, and appears to resist more firmly than the accompanying materials, the decomposing action of the atmosphere, and hence it continues unaltered in places where all the others have been washed away. The specific gravity of this lower band is 3.265.

It loses by calcination,	22.7 per cent.
And gives of iron,	29.4 "
Earthy matter,	36.7 "
Volatile matter, oxygen, &c.,	11.2 "
	100.0

No. 7. This is the middle ply of the ore in the bed near Mason's coal mines. It is found in a stratum of kidney shaped balls, 5 inches thick. Its color, in fresh fractures, is dark bluish gray, surface splintery, occasionally giving conchoidal fractures, compact, and of uniform texture.

Its specific gravity is 3.763.

Heated to 320°, it loses but	0.2 per cent.
Fully calcined, it loses in addition,	29.8 "
Treated with pure lime it yields at once malleable iron, with a little oxide,	45.0 "
Earthy impurity,	4.1 "
Oxygen,	10.9 "

This stratum affords the richest ore which has fallen under my notice from any coal formation, for the sample

above analysed was not a surface specimen, reduced to the state of a hydrate, but a well marked, solid carbonate, with only a thin surface coating of hydrate.

It will probably be found expedient to work it with either No. 1 or No. 3, or with both together, in order to obtain a good, soft pig metal.

No. 8. This ore is found in the upper band of the three already mentioned as occurring together in Mason's bed. It generally presents the appearance of nearly square blocks, or brick shaped masses, 7 inches thick. Above this ply of ore is a course of balls separated from it only by a few inches of friable sandstone ; a coarse quartzose grit lies a little higher. The aspect of this ore when it has not undergone any decomposition by atmospheric influences, is a dark gray color, a rather rough surface, and a mixture of shining metallic particles interspersed through the body of the ore, as well as on its surface.

Its specific gravity is 3.4783.

At 320° it loses,	0.4	per cent.
At white heat it undergoes decomposition and loses,	25.8	"
It smelts without diffieulty, and yields of pig iron,	43.3	"
It contains of earthy impurities fusing into a dirty white cinder,	25.4	"
And the oxygen is,	5.1	"
	100.0	

The pig metal obtained was soft, grey and tough. There is no doubt in my mind that this ore will be found to work well either by itself or with the other ores found in this bed.

No. 9. This specimen was from the stratum of balls, three inches thick, in the above mentioned opening, not far from Mason's coal mines.

Its color is yellowish or dark brown.

Its specific gravity is 3.4977.

At 320° it loses,	0.5	per cent.
Calcined to whiteness, it loses in addition,	25.5	per cent.
And when smelted, yields of pig metal,	45.6	per cent.
Of earthy impurities it contains,	10.7	per cent.
And of oxygen,	17.7	per cent.
	100.0	

This iron is moderately tough, and of a light color, appearing rather less favorable for foundry purposes than the results of the other plies in the same bed.

No. 10. This specimen, as well as the next, was found on Wagner's run, the precise elevation not ascertained. It appears in many respects analagous to the ore in the 37½ inch bed on Fall Creek, being a conglomerate of pebbly masses of clay ironstone, with a cement of earthy and ferruginous matter.

Its specific gravity is 2.823

It contains of water,	9.2	per cent.
It yields of pig metal,	29.8	"
It contains of earthy impurities,	50.	"
Oxygen,	11.	"
	100.	

No. 11. This specimen, as well as the preceding, was found in the channel of Wagner's run, but as there can be no doubt of its having belonged to a regular stratum of ore not yet explored, but of considerable thickness, it was deemed expedient to examine its properties.

Its specific gravity is 3.5065.

It yields 50 per cent. of pig metal, soft, gray, and tough. It resembles strongly the ores found in the bed of Long Valley creek, in some parts in large quantities, and also has a striking similarity to the upper ply in Mason's ore pit. It contains but 8 per cent. of matter insoluble in acids.

From the foregoing details it will be observed that the yield of the several ores is as follows, viz:

No. 1,	32.5
No. 2,	24.2
No. 3,	44.0
No. 4,	53.4
No. 5,	48.4
No. 6,	29.4
No. 7,	45.0
No. 8,	43.3
No. 9,	45.6
No. 10,	29.8
No. 11,	50.0

Mean 40.5 per cent.

Fireclay.

At least three strata of fireclay have been observed on the waters of Fall Creek; one 16 inches thick, under the 37½ inch bed of iron ore; one 4 feet thick, above the 10 feet bed of ore and iron shale; and another, still higher, accompanying a bed of ore under the coarse gritstone or conglomerate. This clay, of the 4 feet bed, has a dark gray color, compact structure, and possesses a specific gravity of 2.646. In the fire it becomes reddish white, but is otherwise unchanged except by cracking, as it shrinks, and displaying on the exterior some traces of oxide of iron.

Limestone.

A sample of the limestone picked up in the channel of Long Valley creek, possesses a specific gravity of 2.7054.

It contains about, ...	40.0	per cent. carbonate of lime.
	3.5	per cent. peroxide of iron.
	56.5	per cent. argillaceous matter.
	100.0	

As the valley of Towanda Creek, below its junction with the Carbon Creek, presents many localities where fossiliferous limestone of lower strata than that above described, are brought into view, it was deemed proper to make also some trials to determine its degree of purity; its color is reddish gray.

Its specific gravity is 2.658.

It yielded of carbonate of lime, ...	45.5	per cent.
It yielded of peroxide of iron, ...	5.5	"
It yielded of earthy argillaceous matter and sand, .	49.0	"
	100.0	

Report of J. T. Hodge.

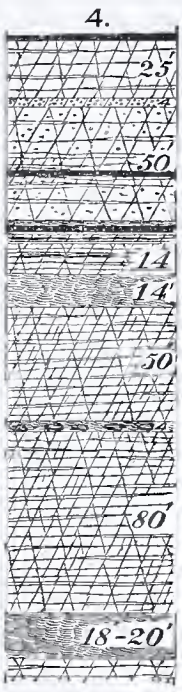
In 1841 the First Geological Survey of Pennsylvania examined and reported briefly upon the Barclay Coal Basin.* The report says:

"The east termination of the coal is upon the mountain between the South Branch and Carbon Creek; the west

* The work was done by Mr. Hodge; and is in the Final Report Vol. II pp. 512–513.

does not probably pass west of the township line of Franklin. Loose blocks of conglomerate are occasionally met with west of that line on the top of the mountain.

The following is a section of the measures at Fall Creek :



Coal,	—	
Sandstone,	25′	
Pea-conglomerate,	4′	
Gray and yellowish S. S. (some layers coarse and somewhat pebbly, some with coal and charcoal,)	50′	
Slate, with fern impressions,	2′	
Coal,	3′	
Slate, with Sigillaria,	1′	
White Sandstone (with coaly matter and impressions,)	3′	
Black Slate and Coal,		6″
White Sandstone, somewhat pebbly, with coaly matter,	14′	
Ferruginous bluish and red shale (position of upper ore bed,	14′	
Yellowish gray fine grained argillaceous S. S.,	50′	
Ferruginous shale, and massive mottled gray concretionary iron ore,	3′ 6″ to 4′	
Yellowish gray fine grained argillaceous S. S.,	80′	
Red Shale,	18′ to 20′	
Sandstone,	—	

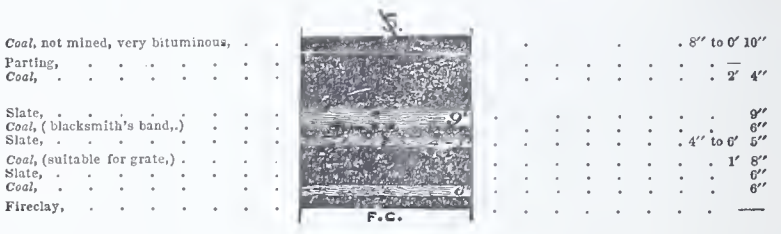
The upper or main bed has been worked at Mason's old mine, 4 miles above the mouth of Carbon Creek, and on the mountain between it and Towanda Creek, where it was found to measure in coal over 4 feet 7 inches ; and also in several places at the old mines 5 miles further west, where it included, according to Mr. Johnson's report, from 5 to 7 feet of coal. The following section embraces the strata in the descending order displayed on the stream at Gatiss' coal mine :

Coal,	6′
Fireclay and sandstone,	20′ to 25′
White Pea Conglomerate (Seral,)	12′
Yellowish SS. and soft shale,	50′ to 60′
Shale and sandy marl,	16′
Umbral S. S.?	—

Between $2\frac{1}{2}$ and 3 miles west of the residence of Mr. Gatiss, the latter has opened a coal bed, and a deposit of

iron ore. The coal is 5 feet 9 inches thick, nearly without slate partings, and has a sandstone roof, and floor of fireclay. The fireclay is quite pure and exceeds 8 feet in thickness. The conglomerate is only 12 or 15 feet below the band of fireclay. It is about 12 feet thick and is underlaid by yellowish sandstone and soft shale. Iron ore was found over the Upper red shale and under the Umbral sandstone. It was not fully opened though as much as 12 feet of shale were cut and found full of balls of rough irregular concretionary ore. It is thought (by Mr. G.) to be a real stratum.

The following are the subdivisions of the coal at Gatiss's :


Coal, not mined, very bituminous, . . . 8″ to 0′ 10″
Parting, ... —
Coal, ... 2′ 4″
Slate, ... 9″
Coal, (blacksmith's band,) . . . . . 6″
Slate, ... 4″ to 6′ 5″
Coal, (suitable for grate,) . . . . . 1′ 8″
Slate, ... 6″
Coal, ... 6″
Fireclay, ... —
F.C.

Two or three species of Sigillaria are found in this coal.

A lower bed which, as the section shows, has been opened on Fall creek, measures about three feet of coal. This bed is the only one to be found on the mountain between Carbon creek, Middle Branch, and South Branch. The top of the mountain is capped by the Conglomerate, which forms upon it, as well as on all the other high parts of the ridge, a bold, white ledge, visible from a distance.

The Conglomerate here is quite coarse, often containing pebbles as large as filberts.

The iron ore under the upper bed lies in three bands, the upper of which yields the best ore. This is a close-grained carbonate, very similar to the ore of the coal measures in the western counties.

At the upper limit of the Vespertine sandstone series, we find on Carbon creek, and in other localities, a comparatively worthless stratum of red iron ore. This ore was opened by Mr. Johnson, on Fall creek, at a level of about 70 feet lower than the more valuable Umbral ore, which underlies the Conglomerate. Here it consisted merely of

silicious and argillaceous materials, cemented together by oxide of iron, with some ore balls intermixed. At other places it appears as a very ferruginous red sandstone."

Although the above reports were sufficient to establish the value of the Towanda coal basin, yet nothing could be done towards developing the region until the North Branch canal should be completed.

Work having been suspended upon this canal, the Barclay coal basin remained untouched until, in 1854, the State having, in the meantime, resumed work upon and almost finished the canal, the Barclay Coal Company prepared to build the necessary miles of railroad from Towanda to Barclay, and to develop the region extensively. Previous to such development, however, Prof. J. P. Lesley and Jos. Lesley made a complete report to the company, giving in detail the acreage of coal bed B. available, and all facts relating to the basin.

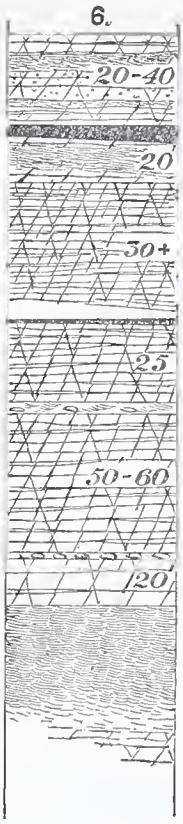
Report of J. P. and Jos. Lesley.

On the map accompanying this report, these areas of coal bed B. are all laid down; being taken chiefly from Prof. Lesley's original map. He reports the Schroeder Creek section thus:

"The vertical sections of coal, and the intermediate rocks, and the vertical profiles drawn upon the same sheet, with the map of the lands, express the order of superposition, and general character of the rocks."

1. On the top of all are softer sandstones and some shales, with a layer or two of very hard and sometimes pebbly rock. Twenty or thirty, and sometimes even forty, feet of these strata form the very highest broad, level summits between the ravines, which cut down southward through the property in the Schroeder. They form roundish, oblong, or dumb-bell shaped knolls and summits, with a disposition to fall off all around in a sloping bluff.

2. Under them lies the upper and large coal bed B, from 5½ to 9 feet thick. It outcrops all around the knobs or flat areas, before described, on the sides of the sloping bluffs, under the sandstones.



3. Below the coal spreads out a terrace of shale and sandstone rocks, say 20 feet thick, to the edge of a system of precipices formed by the ragged edges of the great conglomerate, as it has been improperly called, for its very characteristic feature is the absence of pebbles in a rock so massive.

4. Beneath it are flinty, thin-bedded sandstones, forming the precipices of Fall Creek and other ravines, and bluffs of various heights along the valley of the Schroeder. Thirty feet or so of these sand rocks, with no intermixture of shale, making in all an interval of about 80 feet between the upper and the lower coal beds, bring us down to the latter.

5. The lower coal bed, A, from 1 to 3½ feet thick, with a much more extended outcrop than the upper coal bed, but apparently inferior quality of coal.

6. Twenty-five feet, more or less, of similar flagstone rocks.

7. Four or five feet of shale and clay, with numerous nodules of carbonate of iron.

8. Fifty or sixty feet of flagstone rocks, as before.

9. This is a valuable stratum of gray carbonate of iron (100 feet below coal A) 3 feet thick (on Fall Creek), divided diagonally into large masses by, and reposing upon a variegated clay, of extreme fineness, like fuller's earth. Its tabular fragments pave the bed of the creek between the Falls, and are several feet in length. Its mining will be a very easy process, so long as it retains its character at the Falls. It undoubtedly spreads to a great extent, under the broad summits of the mountain. Johnson's analysis shows it to be a 33 per cent. ore (earth, 30 per cent.; oxygen, 14; water, 24). It interests the geologist to observe that it lies 70 feet above the upper limit of the upper red shale band (XI) and can be discovered elsewhere by that mark. With a proper application of skill and capital, the value of this stratum can hardly be exaggerated; and its present ap-

pearance would justify the erection of a furnace upon the Schroeder branch, where water power would never fail; and the immediate neighborhood of fuel and ore would compensate for the necessity of hauling the flux from a distance, provided a careful trial failed to show a sufficient amount of lime in any of the impure calcareous beds which make their appearance along the creek, below the great Falls.

10. Twenty feet of gray sandstone rocks.

11. Upper band of red shale, (Umbral), formation XI, of the Pennsylvania Reports. Forty-five feet of it are visible, constituting the lower half of the Upper great Fall. It is a marked feature in the geology of the mountain, and forms a steep slope upon the mountain sides of the Schroeder Valley. There is another band of red shale lower down, below which the Vespertine, gray, flaggy sandstones (X) set in for several hundred feet, and below these again, and occupying the whole lower portion of the valley of Schroeder, are the red shales and sandstones of the Old Red Sandstone, the Levant (of Rogers) the IX Formation of the Reports. They are the sandstones which make the rapids and falls of the Schroeder; and here occur the impure limestone layers alluded to in previous reports. Through all the above series of rocks, from 800 to 900 feet thick, not only the Valley of the Schroeder itself, but all the branch vales and ravines opening into it, are troughed down. Nothing can exceed the steepness of these ravines; their streams are a succession of cascades, but their head waters, flowing over the great plateau of sandstone which forms the summit of the mountain, are intercepted in their course, partly by the synclinal structure of the plateau itself, and partly by the innumerable fragments of rock, swept southward across it from its northern edge, overlooking the Towanda Creek.

These head waters spread out into wide, deep, ribbon shaped laurel-swamps, in which a deposit of first drift, then sand, and lastly vegetable mud, has been going on for an indefinite period. These long swamps, stretching north and south across the top of the mountain, sub-divide the

whole area of its summit into a series of coal patches, a continuation eastward of the series on the Barclay lands, next adjoining these on the west. * * * * *

The ground rises westwardly. The streams head up in that direction. The coal rises with them, and this has brought about the result, that all the central and western tracts on the property are wholly denuded of good coal, which can be traced but little beyond the Sunfish Pond on the John Boyd tract.

The lower coal bed, A, may underlie the surface as far as to the head waters of Rollison Run, but from the similarity of the rocks which enclose it, and its own thickness, it cannot without great effort be discovered, and will probably nowhere repay the expense of opening. It is this bed which no doubt furnishes reports of coal on Wolf Creek, Rollison's Run, and the heads of little Schroeder. No calcutions of moment can be based upon the expanse of this lowest coal (A). It has been sought after diligently along the eastern edge of the property, and not found, at least in working size. Where it has been fairly opened at the Falls, on Fall Creek, on the property adjoining to the east, it is a bony, sulphurous coal, not 3 feet thick. Such is its character in the counties further west where it has been preserved from denudation.

The principal bed, B, on the contrary, always affords a pretty good, and generally a superior coal. It is disposed to part into three main layers; the uppermost and middle layers are the best. In the boring (on the North Cox line) it is 10 feet thick, 7.5 of which is coal. Elsewhere it yields 6′ 10½″ of coal in 9′ 2″, and 6 feet of coal in 7′ 6″ of rock. In the new opening made on McKraney's Run, (on the east Joseph Henry line) it shows a solid breast of coal 5′ 9″ thick. Underneath it lies a valuable stratum of white fireclay into which we sank four feet without getting through.

At the old openings at Gatiss's, whence the wagons that visit the mountain get their supply, only three feet of the upper best coal is at present mined, but when efficient means are called for to supply a heavy trade, the whole or most

of the thickness of coal will be taken out. The excellency of its quality is already acknowledged. Blacksmiths value it because it is very free from sulphur, and makes a good hollow fire. In the stove it burns with a rich flame, and leaves little or no ash. Specimens of it from the old mine, and from openings made in it a mile to the eastward, were analyzed by W. R. Johnston, in 1840, and show the presence of only 12 to 15 per cent. of volatile matter. This ranks the coal among the semi-bituminous coals, which are peculiarly fitted for iron smelting and steam generating purposes. It is the same bed of coal which holds so high a reputation in the Broad Top region, and is, I think, quite equal to it in the quality of its fuel. It is also about the same average size with that. It is remarkable that, at so great a distance, this bed B should exhibit such uniformity of disposition. Even the small attendant seam above the Broad Top coal, appears on your property. At Gatiss's there is a small one foot coal bed, about ten feet over the bed B.

The *Iron Ores*, of which I will now speak, have an immense extension across your property. I picked up numerous specimens of the gray ore in the bed of the Big Schroeder, near the southwest boundary line. This is the ore which outcrops in an irregular stratum, three feet thick, beneath the third fall on Fall creek, one hundred feet below coal A, and two hundred feet below coal B. It is, by analysis, a thirty-three per cent. ore, and solid; included both above and below by fireclay, or soft, variegated shale. A drift, five feet high, would have rock top and bottom, clay drivage, and a three-feet plate of ore. It is not in any apparent connection with the true Red Shale formation, the top of which is 70 feet beneath it. All between consists of flag sandstones, as above. The top of the Red Shale is exposed for forty feet, without a sign of iron ore. This bed, therefore, is the representative of the ore of XI, of our Pennsylvania Geologists, traced by Mr. Hodge and myself, as far as the Virginia line.

To show its geographical extent, I refer to Mr. Hodge's Report to the State Geologist, condensed in the Fifth An-

nual Report, where the fact of two Red Shale formations, a hundred feet apart, is mentioned, and the ore described as a stratum six feet thick, one half ore, and four feet beneath the Conglomerate. And again, as a bed of shales from four and a half to six feet thick, the upper half richest in ore, which is nearly solid. It is described as a nodular, white, crystalline proto-carbonate, somewhat resembling a fine-grained sandstone. And again, as spathose or sparry, somewhat laminated, siliceous, gray. Analysis: Protoxide iron, 41.22; silica, &c., 28.80; carbonic acid, 24.00; water, 4.28; alum., 1.00; lime, 0.50.

This ore at Fall creek comes out in immense plates, which have been carried by the freshets a hundred yards below the outcrop, under the Fall. Some of these plates are eight and ten inches thick, and three or four feet long. They are crossed in all directions by sparry bands, showing a disposition in the mass to nodular structure. It is an ore of excellent quality, when compared with carbonates of the coal formation, and will afford, according to Overman, with charcoal and cold blast, an excellent forge iron. But none of the carbonates do well with the hot blast. They require great experience and care in the handling, and are profitable only when the proper skill and capital are expended upon them. They are the chief source of all the iron made in England and Scotland, and they must in time be our chief stand-by, and furnish most of the iron for future use in the United States.

The Gray Ore of Fall creek is likely to outcrop just above the Red Shale, on both sides of all the deeper valleys on the property, and at some future time will bear a value only secondary to that of the coal.

I found many masses of pyrolusite, a binoxide of *Manganese*, in the shingle of the Big Schroeder and its side ravines, and traced them to the foot of the falls, on the Rollison run, at a Barometric level of +370, or about eighty feet above the Schroeder, at the mouth of Rollison's run, and about 210 feet below the point at which line B crosses the upper part of the run. As the dip everywhere to the south of the Little Schroeder is towards the north or

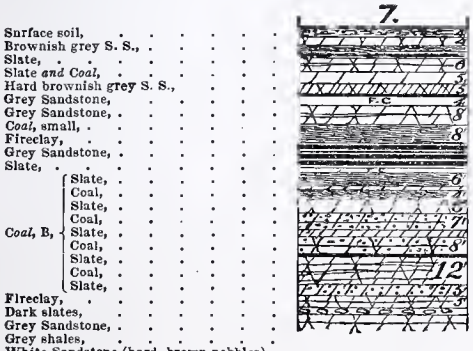
N. N. West from 1° to 3°, I judge this stratum of Manganese to lie about four hundred feet (geologically) beneath the great Conglomerate stratum under coal B, and between the two Red Shale formations.

The size of the lumps was very uniform, and such as to induce the belief that the stratum from which they came was not over six or eight inches thick. The material is in extensive demand for the production of chlorine for the manufacture of bleaching powder, and for glass houses."

These very complete reports sufficiently established the value of the Barclay Coal Basin; and the Barclay Coal Company completed their railroad, 16 miles long, from their new village of Barclay (near Gatiss' mines) to Towanda.

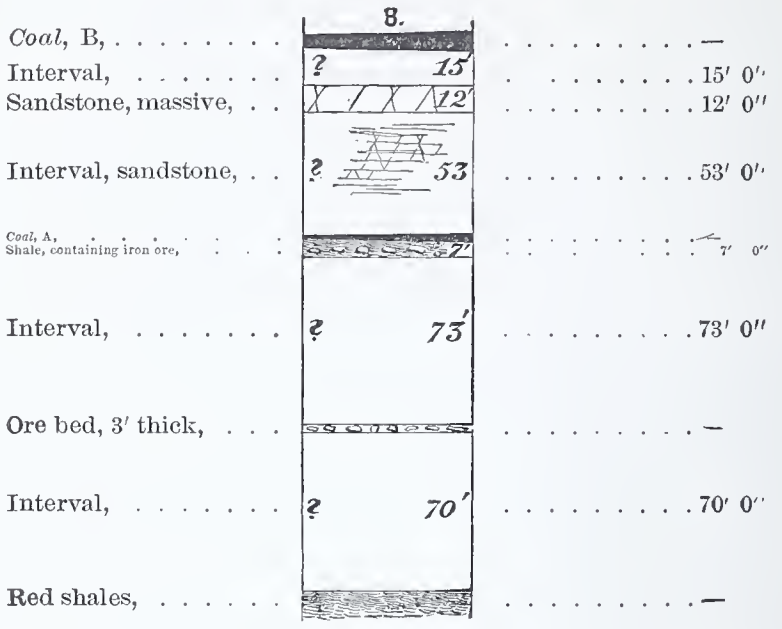
This railroad was completed in time to be ready for business on the finishing up of work on the North Branch canal, and for twenty years the company has been shipping coal largely from their mines. Since 1872 the canal has been abandoned, and a new railroad along the North Branch of the Susquehanna river, the Pennsylvania and New York Canal and Railroad Company, is now the avenue by which the Barclay coal reaches its market.

A boring made many years ago in the property of the Barclay Coal Company, (at the junction of the And. Grayson and Jac. Cox lines,) gives the following section of the measures from the surface down to and through coals B and A:

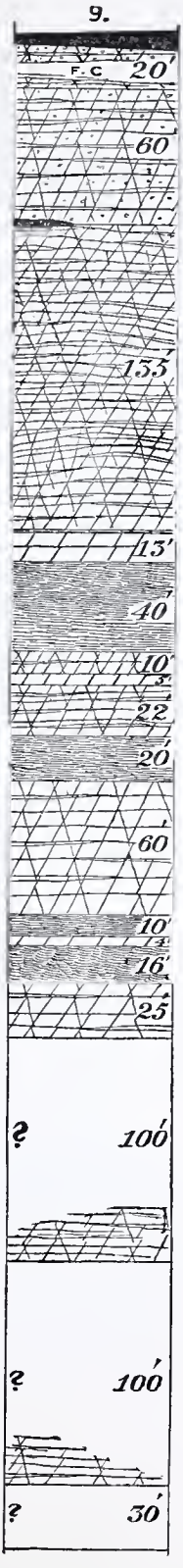


Surface soil,			4′ 0″
Brownish grey S. S.,			4′
Slate,			2′
Slate *and Coal*,			3′
Hard brownish grey S. S.,			6′
Grey Sandstone,			5′
Grey Sandstone,			5′
Coal, small,			—
Fireclay,			4′
Grey Sandstone,			8′
Slate,			8′
Coal, B,	Slate,	1′ 0″	10′ 3″
	Coal,	1′ 9 1-2″	
	Slate,	0′ 10″	
	Coal,	0′ 5 1-2″	
	Slate,	5″	
	Coal,	2′ 0″	
	Slate,	1′ 0″	
	Coal,	1′ 11 1-4″	
	Slate,	9 3-4″	
Fireclay,			2′ 0″
Dark slates,			6′
Grey Sandstone,			2′
Grey shales,			4′
White Sandstone (hard, brown pebbles)			6′
Brown and white Conglomerate,			7′
Brown ferruginous sandstone,			3′
Grey conglomerate,			8′
Coal, small (A ?),			—
Gray and brown Sandstone,			12′
Hard grey brown Conglomerate,			5′
White Sandstone.			5′
Iron Ore ?			—
White Sandstone,			—

Another section of the measures holding coal beds A and B, made on Coal Run gave—


B.
Coal, B, ... —
Interval, ... ? 15′ . . . . . 15′ 0″
Sandstone, massive, . . 12′ . . . . . 12′ 0″
Interval, sandstone, . . ? 53′ . . . . . 53′ 0″
Coal, A, ... —
Shale, containing iron ore, . . . 7′ . . . . . 7′ 0″
Interval, ... ? 73′ . . . . . 73′ 0″
Ore bed, 3′ thick, ... —
Interval, ... ? 70′ . . . . . 70′ 0″
Red shales, ... —

The vertical section from coal bed B down to Schroeder Creek shows thus at the Barclay R. R. incline plane—



Coal B,	—
Fireclay and sandstone underlying,	20′ 0″
S. S., Conglomerate,	60′
Coal A, (place for, not opened)	—
S. S., brown to gray, and grayish white; much current bedded; no conglomerate layers showing, in places very ferruginous and friable,	135′ 0″
Gray fireclay slate,	2′ 0″
Red clay rock, massive,	13′ 0″
Red and gray slate,	40′ 0″
Gray sandstone,	10
Red clay rock,	5′
Gray sandstone,	22′
Red slate,	20′
Gray greenish S. S.,	60
Red slate,	10′
Micaceous sandstone,	4′
Red shale,	16′
Gray sandstone,	25′
Interval, rocks not seen, but gray S. S. near bottom,	100′
Interval, rocks not seen, but gray S. S. near bottom,	100′
Interval,	30′
Foot of Plane,	—

Of the small coal bed 36 feet above coal bed B (see page 125, record of bore hole) nothing further can be said than the fact there given. It is reported as 3 feet thick; but this probably includes roof and parting slates, and cannot be depended on as a measurement.

A coal apparently overlying coal bed B by about the same interval distance was once opened in the crop over towards the eastern end of the basin. It was small, and gave no evidences of possessing value. These are the only two openings on it recorded.

It may be dismissed therefore as of unknown size and character in the Barclay basin, but with strong indications that it is small and worthless.

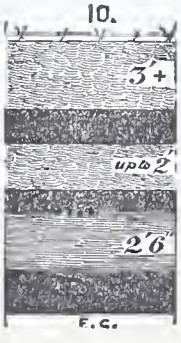
The small coal 20 feet above coal bed B is under a foot in size, and has no commercial value.

Coal Bed B is the bed which has given in the past and now gives its value to the Barclay Coal basin. The day will doubtless come when coal bed A will be worked at various points and much coal shipped from it; but at present, as in the past, all the coal going to market from the Barclay basin is yielded by coal bed B.

Coal is mined and shipped in large quantities from the Barclay Mines of the Barclay Railroad and Coal Company, and from the Schroeder Mines of the Carbon Run Coal Company.

Barclay.

At Mine No. 1 of the Barclay Mines, the coal measured



Sandstone on top,	—
Roof slate,	3′ 0″ +
Coal, top bench,	1′ 6″
Slate,	—up to 2′ 0″
Coal,	1′ 0″ to 1′ 2″
Slate,	2′ 6″
Coal,	1′ 10″
Fire clay floor,	—

The coal in the lower bench is friable, columnar, deep black, free from slate.

The middle bench is friable, columnar, black.

The upper bench, cubical, harder, does not crumble, and has no regular slate layers.

This is one measurement; but the measurements given below, all made in the present mines of the Company, are taken from the notes of F. F. Lyon, Chief Engineer, and show the great variations in size to which the coal bed is subject:

Sandstone on top,	—
Slate roof,	10′ 0″
Coal,	5′
Fire clay floor,	—

There are no slate partings at this place, and yet the coal is clearly in three benches as before; the benches being defined, not by slate partings, but by the structure and appearance of the coal.

Another measurement gives—

Slate roof,	—
Coal,	1′ 9″
Slate,	8″
Bone coal,	6″
Coal,	8″
Slate,	6″
Coal,	2′ 6″
Fire clay floor,	—

And again:

Sandstone roof,	—
Coal,	1′ 6″
Slate,	1′ 0″
Coal,	2′ 0″

And again:

Sandstone roof,	—
Coal,	1′ 10″
Slate,	0′ 2″
Coal,	6″
Slate,	6″
Coal,	10″
Fire clay floor,	—

And again:

Slate roof,	—
Coal,	1′ 6″
Slate,	2′ 0″
Coal,	1′ 3″

Fire clay,	1′ 0″
Slate,	0′ to 6′ 0″
Coal,	2′ 9″

These variations are very great, and within comparatively short distances.

The roof varies equally rapidly; in Mine No. 1, there is entirely a slate roof; while in Mine No. 2, (close by) there is almost entirely a sandstone roof.

In working the Barclay mines they have passed through a disappearance and re-appearance of the bottom bench of Bed B which is so unusual in its features as to call for special comment.

The following letter from Mr. F. F. Lyon, Mining Engineer of the Towanda Coal Company, and the accompanying illustration, (Page Plate I,) will explain the case clearly.

Under date of Barclay, Nov. 2, 1877, Mr. Lyon writes thus:

"When you were here we were talking about the peculiarities of the coal basins of the State of Pennsylvania.

"We have just passed through one of those, and thinking perhaps that it might be of interest to you as a Geologist, I have endeavored, by a rough sketch, to show you something of its nature.

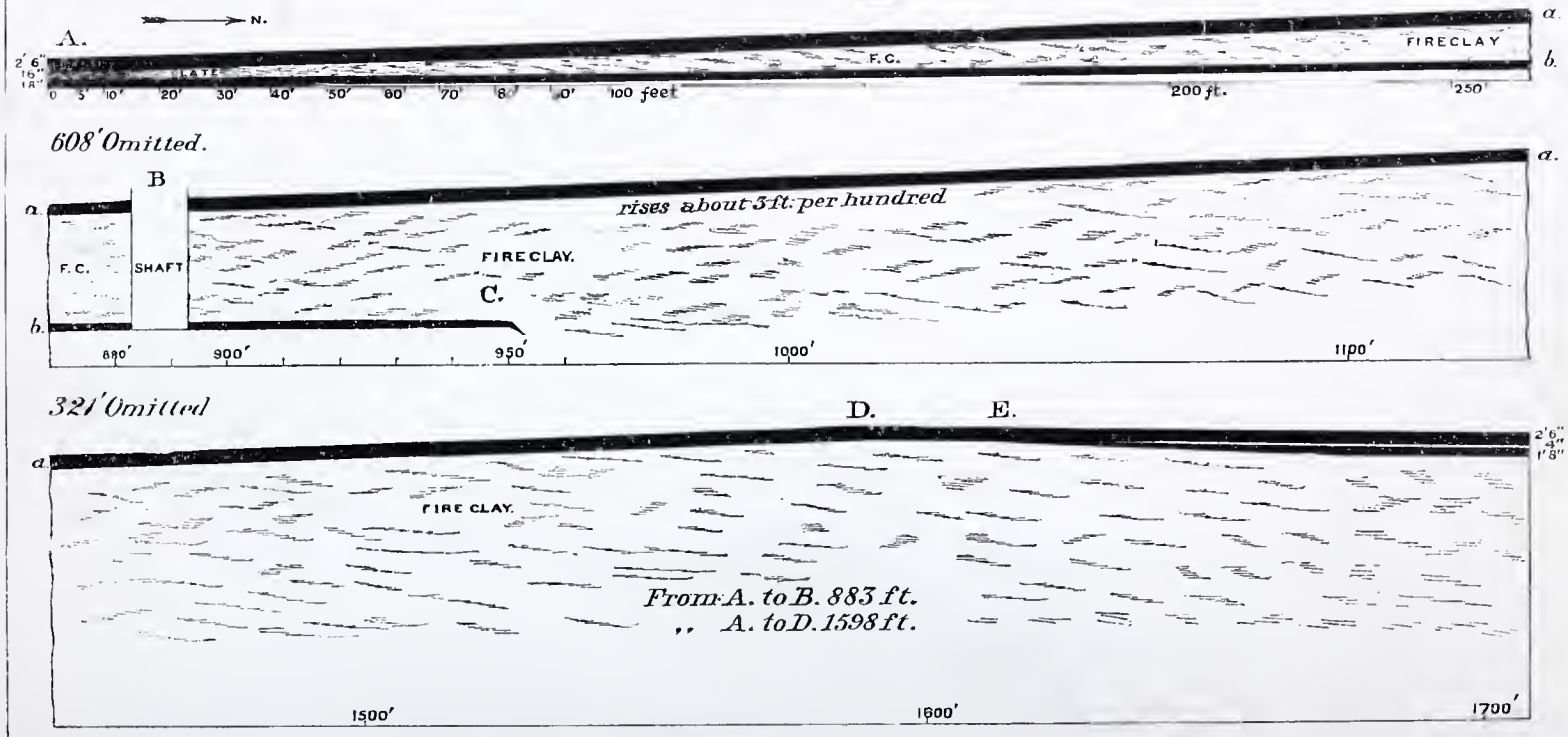
"At the point A on the sketch, you will observe that we have the vein lying perfectly natural, viz: bottom coal, 18 inches in thickness; top coal, 2 feet 6 inches in thickness, separated by 16 inches of slate, and all with a gradual raise to the north.

"At this point (A) the slate begins to thicken, and also to change from a slate to a very hard fireclay, so that when it reaches the point B, a distance of 883 feet, instead of having the 16 inches of slate, we have about 19½ feet of very hard fireclay, both seams of coal remaining the same, and retaining their full thickness; the bottom seam running, however, but about 40 feet further, when it begins to lessen, and in 30 feet further it wedges out entirely, and is lost in the heavy bed of fireclay, (at C,) the latter part dipping very rapidly.

"The top seam continues on, raising about 3 feet to the

Fig.11.

Isolated lengths of longitudinal Section to illustrate Variations in Barclay Coal Bed (B.) furnished by Mr F. F. Lyon.



100, with fireclay bottom, until it reaches the point D, a distance from A of 1,598 feet.

"At this point (D) the vein begins gradually to go to the dip, and at E, a distance of 25 feet, we first discovered signs of the slate and bottom coal returning, and in going about 100 feet, find the vein again as regular as at A, with the exception of the slate, which is considerably thinned, being but 4 inches in thickness."

This case of variation of parting thickness of seams of the same coal bed, the whole case being plainly in view, and all within a distance of less than 600 yards, is of interest in connection with the long-continued discussion on the parallelism or non-parallelism of coal beds; as it shows how readily imperfect facts may lead into erroneous conclusions.

For if, instead of one continuous mine opening, there were outcrop openings at A and E, and the shaft at B; the latter would of course show two coal beds, 20 feet apart, separated by fireclay, while A and E would show one coal bed with a slate layer, and no coal bed 20 feet below: the inference being that the lower coal bed had absolutely disappeared.

Without re-opening here the question of the parallelism of coals, it may be stated that in the work of the Second Survey of Pennsylvania there has been nothing developed as yet, (in the facts in the published reports,) which would call for any re-shaping of the conclusions reached by Prof. Rogers, and clearly stated in the Final Report of 1858, where he shows that while the normal condition of coal beds is one of parallelism, sometimes over very great areas, yet there are numerous instances of great local variation in interval distances, many such variations being pointed out as occurring in Pennsylvania.

Taking Coal Bed B, with all its variations, at the Barclay mines, and it averages about 5,000 tons to the acre, or $3\frac{1}{4}$ feet of clear coal.

A specimen of the upper bench of the coal yielded, on analysis, (McCreath):

(The coal is generally bright and crystalline, but has some thin, slaty seams of slaty coal. It is rather tender, and carries numerous thin partings of mineral charcoal:)

Water,	.730
Volatile matter,	17.220
Fixed carbon,	69.840
Sulphur,	.795
Ash,	11.415
	100.000
Coke, per cent.,	82.05
Color of ash,	Gray.

A specimen of the middle bench of the coal yielded, on analysis (McCreath):

(The coal is generally bright and columnar, with numerous bands of slaty coal. It carries considerable slate in thin seams, and also in lenticular masses:)

Water,	.760
Volatile matter,	16.405
Fixed Carbon,	62.172
Sulphur,	.613
Ash,	20.050
	100.000
Coke, per cent.,	82.835
Color of ash,	Gray, with yellow tinge.

A sample of the coal selected from the bright crystalline portion was analyzed separately:

Water,	.750
Volatile matter,	17.070
Fixed carbon,	71.969
Sulphur,	.661
Ash,	9.550
	100.000
Coke, per cent.,	82.18
Color of ash,	Gray.

A specimen of coal from the lower bench yielded, on analysis (McCreath):

(The coal is bright and columnar, also cannel-like and resinous. The crystalline coal is very tender, and carries numerous thin partings of mineral charcoal. It has a bright, black lustre, and breaks with cubical fracture.)

Water,	.880
Volatile matter,	16.660
Fixed carbon,	73.257

Sulphur,	.643
Ash,	8.560
	100.000
Coke, per cent.,	82.460
Color of ash,	Gray.

Specimens of the bright crystalline columnar coal, and of the cannel-like coal, were analysed separately.

Crystalline Coal—(McCreath.)

Water,	.850
Volatile matter,	17.080
Fixed carbon,	75.939
Sulphur,	.681
Ash,	5.450
	100.000
Coke, per cent.,	82.07
Color of ash,	Gray.

Cannel-like Coal—(McCreath.)

Water,	.900
Volatile matter,	15.050
Fixed carbon,	71.396
Sulphur,	.544
Ash,	12.110
	100.000
Coke, per cent.,	84.05
Color of ash,	Gray.

The cannel-like coal yields a coke which is only slightly coherent.

An average specimen of the whole of Bed B, as mined at Barclay, representing the run of the mines, as shipped to market, yielded, on analysis (McCreath):

(The specimen consists of bright, tender columnar coal, seamed with mineral charcoal and some slate partings; and also of compact, resinous cannel-like coal, with conchoidal fracture.)

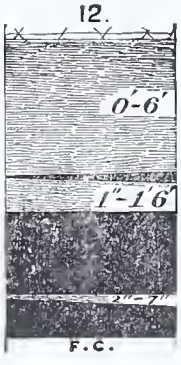
Water,	.770
Volatile matter,	17.110
Fixed carbon,	70.744
Sulphur,	.776
Ash,	10.600
	100.000

Coke, per cent.,	82.12
Color of ash,	Gray.
Sulphur left in coke,	.565
Per cent. sulphur in coke,	.688
Per cent. iron in coal,	.168
Sulphur taken up by iron,	.192
Free sulphur,	.584
Per cent. sulphur volatilized by coking,	27.190

Carbon Run.

The Schroeder Mines are opened on Coal bed B, about 1½ miles west of Barclay. A railroad from the head of the Barclay incline plane to the mines gives an outlet for the coal on to the Barclay RR.

Coal B as measured in the Schroeder Mine shows:



Sandstone roof,	—
Slate,	0 to 6′ 0′
Coal, upper,	1″ to 0′ 6″
Slate,	1″ to 1′ 6″
Coal, middle,	3′ 7″
Slate,	2″ to 0′ 7″
Coal, lower,	1′ 8″
Fire clay,	—

The upper bench is friable and columnar, irregular in size, of good character, and is the "blacksmith coal" of the mine.

The middle bench is harder and cubical in structure.

The lower bench is friable and columnar.

Specimens of the middle and lower benches yielded on analysis (McCreath):

"The specimens consist of bright crystalline columnar coal and grayish black cannel-like coal.

The middle (3′ 7″) bench yields:

Water,	.940
Volatile matter,	17.845
Fixed carbon,	72.155
Sulphur,	.670
Ash,	8.390
	100.000
Coke, per cent.,	81.225
Color of ash,	gray with yellow tinge.

The specimen from the bottom bench (1′ 8″) contained the more slaty coal. The bright coal is tender and is seamed with mineral charcoal and iron pyrites.

Water,	.850
Volatile matter,	16.755
Fixed carbon,	69.390
Sulphur,	.715
Ash,	12.290
	100.000
Coke per cent.,	82.495
Color of ash,	gray with yellow tinge.

The coal bed of the Schroeder Mines is about at its average maximum of size and character. It yields about 6,000 tons of coal to the acre. The mines ship steadily about 700 to 800 tons daily.

The Schroeder Mines are near the western end of the basin so far as coal bed B is concerned; the old "west opening," about ⅔ mile west of the Schroeder being the west outcrop of B. The bed is here rising to the west and does not come in beyond Sunfish lake, so far as could be determined by this examination.

Mines East of Barclay.

The Barclay Mines have been fully described.

To the east of the Barclay mines there are numerous trial openings on bed B, but no mines are opened for shipment to market.

An old opening on McKraney's Run showed:

Cover, massive sandstone,	20
Coal (nearly all solid coal,)	5′ 9″
Fire clay,	4′ 0″ +
Interval,	15
Massive sandstone, Conglomerate,	12′ 0″

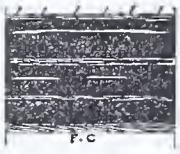
On the property 3 miles east of Barclay numerous test openings have been made on coal bed B. They show it in a natural condition, of good quality, and averaging over 3 feet of coal. Mr. Lyon made these test pits and states the facts as above. The pits are now closed.

At the extreme east end of the basin are the old *Mason Mines*, once quite important mines when coal was hauled

from there by wagons to supply a considerable region, the coal going up into New York State.

Though not now worked, yet the coal bed could be examined at these mines and showed—

13.



Roof, massive sandstone,	—
Coal, bony,	0′ 1 1-2″
Coal, some slate,	1′ 7 1-2″
Slate (and coal),	3 ″
Coal, some slate,	1′ 4 ″
Slate and bone,	2 ″
Coal,	1′ 0 ″
Black slate,	4 ″
Fireclay ?	—

And again it measured—

Roof, massive sandstone,	—
Coal, bony,	0′ 1½″
Coal, some slate,	1′ 3 ″
Slate,	3 ″
Coal, some slate,	3′ 0 ″

The sandstone roof is firm and regular, and the coal comes out close to the outcrop as firm hard coal. But in both openings the solid coal layers are intermixed with fine layers of slate, too small to be separable in mining, and which must add largely to the percentage of ash in the coal, and very materially injure it in competition with mines where the bed is purer.

The old *Northrop Mine*, also on bed B, not far from the Mason Mine, is now fallen entirely shut; it shows the same massive sandstone roof, filled with Lepidodendron impressions.

About 125 yards south southeast of the Northrop Mine, and 14 feet lower than it on level, a coal bed is opened up in a shallow pit on a flat. It looks much like a break off from bed B, though the Coal shows differently. The pit shows:

Surface,	1′ 0″
Yellow slates,	1′ 5″
Coal,	5′
Slate,	3″
Coal,	2″
Slate,	1′ 0″
Coal,	3″ to 6″
Slate,	3″
Coal,	3″
Slate,	1′ 10″

Coal,	4″
Slate,	5″
Coal,	0′ 2″
Slate in bottom,	—

This worthless mass of coal and slate is nowhere else found under bed B in the basin; so it is most probably a slip down on that bed.

At *Anderson's House*, in the cellar, a coal showing 2 feet thick, was struck in the outcrop. Only loose stuff was overlying, and in the absence of any solid rock in place it is doubtful if the full thickness of the bed was visible at this place.

An old exposure, 200 yards south of Anderson's House, shows a coal, with massive sandstone roof.

And 300 yards further south there is an old opening now fallen shut. No measurements could be made in any of these openings.

South of the Schroeder Creek.

At the eastern end of the Barclay Coal Basin, west of Lamoka Station on the Barclay Railroad, the hills on the south side of the Schroeder rise somewhat higher than those on the north side, or rather the first abrupt rise is greater.

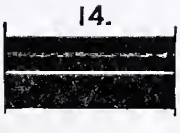
The summit of this high and narrow ridge apparently takes in coal bed B over a limited area. What this area is cannot be exactly stated without running out the outcrop lines. As plotted roughly on a property map the area is small, and much of that would be crop coal.

The openings and borings into bed B as made in the region south of the Schroeder are thus given by F. F. Lyon, the engineer in charge of the work.

"That bed B is 1925 feet above tide on the south of the Schroeder; while at the Mason Mine on the north side it is 1880 feet above tide; showing the rise of the coal to the pointing out of the basin.

That the cover over the coal averages 40 feet.

That on boring down the bed was found thus:



Coal,	0′ 8″
Slate,	0′ 3″
Coal,	0′ 7″
Slate,	0′ 2″
Coal,	1′ 6″

And that a second boring found the same thickness of coal and parting slates."

These figures are given exactly as reported by Mr. Lyon. This report therefore confines itself to the statement that there is apparently a small area of bed B south of the Schroeder, opposite the Mason Mine; the area and the quality of the coal, as well as the average thickness being easily determinable at any time when such facts may be needed.

It will be noticed from the facts already given that coal bed B is of larger size and cleaner from slate in the western half of the basin; and while it varies much at all points in size and character yet the average condition of the bed at the Schroeder Mines, and the Barclay Mines, is certainly superior to the average condition, (taking in both size and character,) as developed by the test openings to the east of those points.

Subject to local variation this may be broadly stated as the condition of the bed in the Barclay basin.

Coal Bed A in the Barclay Basin.

Between Coal bed B and Coal bed A the rocks are usually sandstone; the upper 12 feet (directly under the fireclay floor 4+ feet thick) being made up of massive sandstone, not always conglomerate but frequently so; while the sandstone from there on down to bed A is almost invariably filled to some extent with layers of pebbles.

The coal A has been opened in many places, but has been nowhere mined for shipment to market.

Where opened on *Fall Creek* it showed:

Sandstone overlying,	—
Sandy blaek slate,	5′ 0″
Coal,	1′
Slate,	7″
Coal,	8″
Slate,	6″
Fireelay floor,	—

A specimen of this coal was forwarded to Harrisburg for analysis and yielded (McCreath):

(The coal is very compaet, with dull resinous lustre. It breaks with eonchoidal fracture and has the general appearance of a cannel eoal.)

Water,	.850
Volatile matter,	16.625
Fixed carbon,	67.292
Sulphur,	.498
Ash,	14.735
	100.000
Coke, per cent.,	82.525
Color of ash,	Gray.

The coal yields a coke which is only slightly coherent.

Coal bed A has been opened repeatedly for measurement in the region east of Barclay.

It is reported as having shown from $2\frac{1}{2}$ to 3 feet of good coal in these numerous trial pits. They were made for a special examination, and are all now closed.

A trial opening, on *Cash Run*, near the eastern end of the basin, on bed A, is reported to have found 3 feet of coal. It could not be seen or measured. The measures there are:

Sandstone, massive,	10′ to 20′
Clay slates, dark colored,	5′ to 6′
Coal, bed A, reported 3 feet thick, with one small slate parting.	

Wherever this coal bed A reaches $2\frac{1}{2}$ to 3 feet in thickness it will prove a very valuable deposit. It is of good character; spreads over a broad area; lies well for mining; and is, for the greater part, as accessible as coal bed B.

No openings have ever been made upon it on the south side of the Schroeder creek, nor on any of the detached hill tops where it may have caught west of the Schroeder mines.

Iron Ores.

The Iron Ores of the Barclay Coal Basin have been fully described in the report of Prof. W. R. Johnson. (See p. 115 of this volume.)

The ore below coal bed A on Fall creek shows thus:

Coal bed A,	—
Fireclay,	—
Sandstone,	35′ 0″
Clay, gray,	2′ 6″
Clay, iron stained,	2′ 0″
"Ore,"	4′ 0″
Sandstone	—

The ore is only a very ferruginous clay, carrying an un-

usually large percentage of iron; but would be totally worthless as an iron ore.

At a distance of 150 feet below coal bed B, where it shows at the west opening of the Schroeder mines, there is an exposure of 10 feet of red slate. It is rich red in color, averaging probably 10 per cent. to 12 per cent. of metallic iron, and has always been called an iron ore.

It can possess no commercial value.

The proto-carbonate iron ores which were opened by Prof. Johnson for measurement and analysis are now closed up, and his records can be accepted as fair and reliable for all facts stated in his report.

Character of the Barclay coal.

The following table shows the analyses of the coals from the Schroeder mines and from the Barclay mines, conveniently grouped for comparison:

	Bed B, Barclay.				Bed B, Schroeder.		Bed A, Fall Creek.
	Upper bench.	Middle bench.	Lower bench.	Average.	Middle bench.	Lower bench.	
Water,	.730	.760	.880	.770	.940	.850	.850
Volatile matter.	17.220	16.405	16.660	17.110	17.845	16.755	16.625
Fixed Carbon,	69.840	62.172	73.257	70.744	72.155	69.330	67.292
Sulphur,	.795	.613	.643	.776	.670	.715	.498
Ash,	11.415	20.050	8.560	10.600	8.390	12.290	14.735
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Coke per cent.,	82.05	82.835	82.46	82.12	81.215	82.495	82.525
Color of Ash,	Gray.	Gray, yellow tinge.	Gray.	Gray.	Gray, yellow tinge.	Gray, yellow tinge.	Gray.

An average of six analyses of coal from bed B at Barclay and Schroeder Mines, gives the following result:

Water,	.822
Volatile matter,	16.999
Fixed carbon,	69.593
Sulphur,	.702
Ash,	11.884
	100.000

Leaving out the impurities, and counting only ignitible constituents, we have:

Carbon,	80.369
Volatile matter,	19.361
	100.000

And the relationship of volatile hydro-carbon to fixed carbon, 1 to 4.0939.

The Barclay coal is therefore a true semi-bituminous coal. Nearly all the coal produced from the basin is used for generating steam on the locomotives of the New York and Erie Railway, and the New York Central Railway, or on their connecting roads ; but it is an admirably strong and efficient fuel for all purposes for which semi-bituminous coal is used.

Barclay Coal Production.

The following statistics of the coal trade of the Barclay coal basin from 1857–1877, are furnished by H. Shaw, Treasurer of the Barclay Coal Company.

There has been transported over the Barclay Railroad, from the Barclay Coal Basin, in Bradford county, from the opening of the road in 1857 to 1877, inclusive:

1857 to 1867,	559,588	tons.
1868,	73,901	"
1869,	180,726	"
1870,	273,335	"
1871,	378,334	"
1872,	382,843	"
1873,	337,394	"
1874,	337,389	"
1875,	373,719	"
1876,	383,984	"
1877,	362,652	"
	3,643,865	"

Of semi-bituminous coal produced from the following mines, viz :

Barclay Coal Company,	2,165,063	tons.
Schroeder Coal Company,	626,508	"
Fall Creek Coal Company,	525,186	"
Towanda Coal Company,	327,108	"

Chapter XII.

The Blossburg Coal Basin in Tioga County.

The Blossburg Coal Basin is a canoe shaped synclinal basin, remarkably symmetrical, extending from a point just beyond Fall Brook on the east, to and beyond the Bache Mine on the west side of Wilson's Creek.

The general strike is about North 19° E. and South 19° West.

The basin begins on the east with the region lying north of the Fall Brook Company, and known as the "Ward Lands." This large property, over 3,000 acres, has never been opened for shipment to market; but from reports of Messrs. Coryell, Lyman and others it is clearly, in part at least, in the producing measures of the coal basin.

Next to the south and west is the Fall Brook Company, with its extensive mines and improvements at Fall Brook.

West of this the Morris Run Mines and Village.

Blossburg village comes next; it is not now a shipping place for any coal mined close to the village; the last shipment over the plane having been about 1857.

West of Blossburg is Arnot, the seat of the mines and improvements of the Blossburg Coal Company.

West of Arnot is Antrim, where the Fall Brook Coal Company have a large and complete plant.

West of Wilson's Creek there are only a few country mines, and the basin is rising out to a canoe shaped point; this latter being probably not more than a few miles west of Wilson's Creek.

Along the length of the Blossburg Basin, a distance of about twenty miles, in an air line, the width of the basin varies somewhat, averaging say three miles.

The illustration (Page Plate II) representing a cross section of the Basin at Arnot, from side to side, looking west, shows the Conglomerate rim of the basin on its North and South side, how the North outcrop is 120 feet higher than the South outcrop, and how much the centre of the basin is below the outcrop on the North side.

In fact in all its geological features the Blossburg basin displays a singular symmetry.

In all synclinals it may be said to be the normal condition of affairs for subordinate cross rolls to interfere locally with the general harmony of the basin. But in this region a ruler laid upon the map will strike with its edge on a straight line close to Fall Brook, at Morris Run, at Blossburg, at Arnot and at Antrim. These are the lowest points in the basin, all of them at the true centre of the synclinal, and they are almost in a dead straight line.*

Of the general features of the basin but little need be said. Broadly speaking the enclosing mountains are capped by the massive Conglomerate of XII; on their outer sides, away from the basin, are steep slopes of XI, X and IX, down to the deeply cut surrounding valleys; while on the inside of the basin are hills of less height, though equally rugged, made up of the Lower Productive Coal Measures, which here contain so much massive sandstone as to cover nearly every hill slope with rocky masses, and make the surface wild and barren.

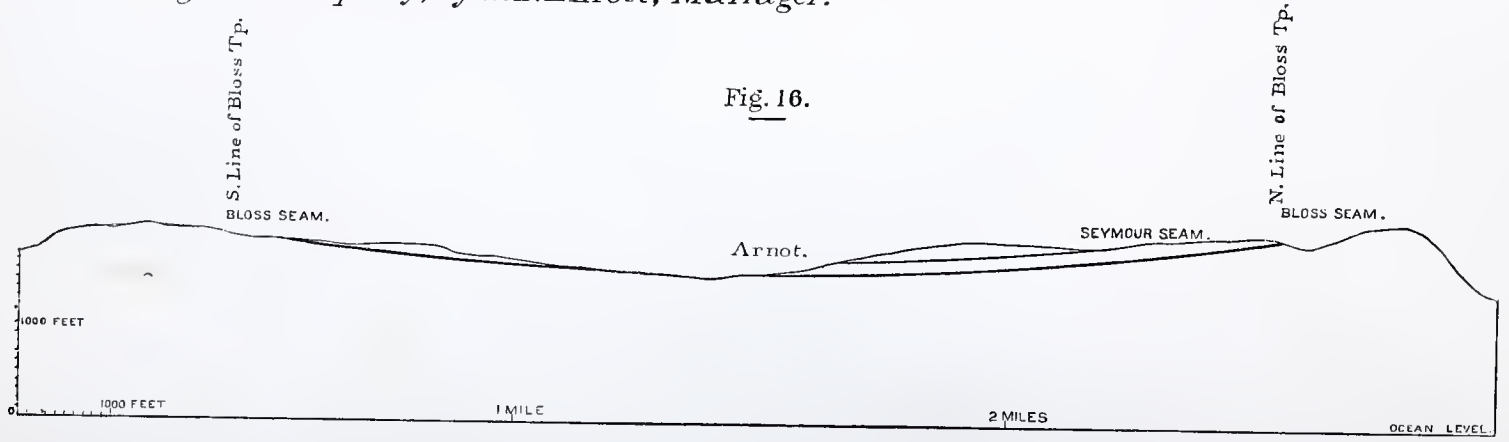
The cutting streams are the important feature of the Basin.

On the Eastern side of the Basin the different streams which drain that part unite near Blossburg and flow north, by the Tioga River, into the North Branch Susquehanna, or Chemung, at Corning, New York; and on the Western side the basin is drained by the equally deep cutting Babb's Creek, or Second Fork of Pine Creek, and by Wilson

* Morris Run is 1678′ above tide.
Arnot is 1682′ above tide.
Antrim is 1672 above tide.
These are at the centre of the synclinal, and are on a straight line.
Fall Brook is not at the centre of the synclinal, and is out of line. It is 1842 feet above tide.

Section across the Coal basin at Arnot in Tioga County, looking westward; showing the main or "Bloss Seam," bed B, outcropping at the North Bloss township line, 412' above its outcrop in the centre of the synclinal at Arnot; and showing also bed C lying 154' above the Bloss bed, B. Published by permission, from a drawing made for the Blossburg Coal Company, by S. B. Elliott, Manager.

Fig. 16.



Creek, a branch of Babb's Creek; these Pine Creek waters reach the West Branch Susquehanna below Lock Haven in Clinton County, Pennsylvania.

The draining streams of the basin represent an enormous destruction of coal area, which destruction is of course always greatest where the coals lie as these do near the hill tops; but they afford an easy and economical outlet for almost every acre of coal land left in the basin. They enable the loaded trains to have always down grade; the up-grade against the empty cars.

Geographically the Blossburg Basin occupies a commanding position for the cheap supply of soft coal to the markets of New York State. There is ample railroad communication, in fact rather more than the annual shipment would at present seem to call for.

The Fall Brook Coal Company own their track from the Fall Brook Mines to Blossburg; the coal then goes over the Tioga Railroad to Lawrenceville; and over the Corning, Cowanesque and Antrim Railroad to Corning, and beyond.

The Morris Run Coal Company have their own track from the mines to Blossburg; from that place this coal goes by the same route as the Fall Brook Company.

The Blossburg Coal Company have their road from the mines to Blossburg; and also the Tioga Railroad from Blossburg to Elmira, New York. This railroad connects at Lawrenceville with the Corning, Cowanesque and Antrim Railroad, and is as above stated the line by which the Fall Brook and Morris Run Companies reach the C., C. and A. R. R.

The most important single outlet is the Corning, Cowanesque and Antrim Railroad. This is under the same control and management as the Fall Brook Coal Company.

The railroad starts at Antrim, runs to Corning, New York, (via Lawrenceville, where it receives the coal of the Fall Brook and Morris Run, both of them under this same management;) from Corning the same railroad, (under the name of the Corning, Geneva, and Syracuse Railroad,) carries the coal freights north, delivering them finally on to

the New York Central Railroad, and thus with connections reaching all points in New York, on the lakes, or in Canada.

The railroad distances to put the Blossburg Coal upon the line of the New York and Erie Railroad at Corning are as follows:

Fall Brook to Corning,	. . . . .	48 miles.
Morris Run "	. . . . .	45 "
Arnot "	. . . . .	45 "
Antrim "	. . . . .	52 "

And the distance from—

Arnot to Elmira is . . . . . 49 miles

DETAILED REPORT.

Although the existence of coal beds near Blossburg has long been known, no systematic attempt was ever made to ascertain the thickness and character of the coal and iron ore beds until the year 1832, when Richard C. Taylor laid out the route of the railroad from Blossburg to the New York State Line and at the same time examined the mineral resources of the Blossburg Basin.

Report of R. C. Taylor.

Mr. Taylor's Report, published in 1833, contains eight detailed vertical geological sections; none of them absolutely complete, but yet having in them many facts, not now re-obtainable except by special opening for the purpose, concerning the carbonate iron ores of the basin.

The vertical sections are:

1. East Creek.
2. Bear Creek.
3. Coal Run.
4. Morris Run.
5. Boon Creek.
6. Johnson Creek
7. Tioga Valley.
8. Fellow's Creek.

1. East Creek Section.

1. Ground partially examined, consisting of sandstone, black slate, and shale, with traces of coal beds, . .	150′
2. *First coal vein*, ...	20′
3. Black slate and fire clay, ...	
4. Sandstone shelf, ...	

5. *Second vein of coal.*
6. Black shale, ... 36′
7. *Third vein of coal.*
8. Black slate, Deer Lick, ... 6′
9. *Fourth*, or three feet vein of *soft coal*, like Clement's coal, ... 3′
10. Black slate, fire clay, and hard shale, ... 9′
11. *Fifth vein of soft coal.*
12. Black shale, ... 5′
13. *Sixth, cannel coal*, thickness not proved.
14. Hard black slate, floor of coal vein.
15. Hard sandstone rock a fall of ten feet on the creek. Dip of the strata, south, ... 10′
16. Sandstone rocks, obscured with alluvium, ... 34′
17. *Coal* and fire clay, estimated position.
18. Sliding bank, ... 108′
Concealed to forks of creek, ... 144′
19. 20. Sandstone series of rocks obscured by alluvium. ——
Total, ... 525′

NOTE.—No coal has been raised in this valley at present. The only proved vein at the outcrop is the third vein in this section.

It may be remarked, that so far as it is possible to form a comparison, the main body of the coal in this valley is 120 feet above that on Bear Creek and Coal Run.

There appear indications of coal as high as from 530 to 550 above the Tioga in this section.

The base of this section at the confluence of East Creek and the Tioga River, is 65.82 feet below Blossburg, and 31 feet below the base of Bear Creek section.

2. *Bear Creek Section.*

1. From summit of mountain flat the strata consist of sandstone, with numerous vegetable impressions belonging to the Coal Measures, and traces of slaty coal in the gullies. Estimated thickness at this point, at $1\frac{1}{4}$ miles up the creek, ... 50′ 0″
2. *Highest coal vein*, obscurely traced, 470 feet above the Tioga River, ... doubtful.
3. Thin sandstone lamina, with abundance of impressions of coal plants. Fragments of coal slate washed down the gullies, . . 50′ 0″
4. Course of good argillaceous *ball iron ore*, weight, 201 pounds per cubic foot; also, some cores of weak, sandy ore in the run.
5. Coal, sandstone, slate, micaceous sandstone, in thin beds, vegetable impressions, mineral springs, . . . 50′ 0″

6. *Second coal vein*, its thickness not proved, 370 feet above Tioga River, 330.02 feet above Blossburg, .		
7. Argillaceous slate and shale, ...	15′	1″
8. Firo clay, ...		
9. Slate, with courses of balls of good *iron ore*, ...		
10. *Third coal vein*, the thickness is not yet ascertained.		
11. Argillaceous slate, ...	7′	11″
12. *Fourth coal vein* of uncertain thickness, 307.02 feet above Blossburg, ...		
13. Argillaceous shale and slate beds, Several courses of good argillaceous *iron ore* in balls, Slaty rock and blue shale.	22′	9″
14. *Fifth coal vein*, called Clement's coal, of exeellent bituminous quality, worked about 30 yards under the hill, 321 feet above the Tioga, 281.05 feet above Blossburg, ...	3′	3″
15. Black shale and occasional rock, ...	8′	0″
16. *Sixth coal vein*, called Bloss' Vein, now worked 269.80 feet above Blossburg, ...	3′	3″
17. Hard compact sandstone and slate, but varying in different points, ...	1′	9″
18. Rock, variable, ...	12′	0″
19. *Seventh coal vein*, not yet proved, ...	doubtful.	
20. Sandy, weak ore, in coarse oval masses and concretions —ground partially examined—for the most part consisting of gray laminated sandstone, and shale occasionally, probably containing coal and iron ore, . .	44′	0″
21. *Eighth coal bed*, not yet proved.		
22. Sandstone, shale, and slate beds, estimated aggregate thickness, ...	20′	0″
23. Good fire clay, thickness not proved, 192.05 feet above Blossburg, ...	15′	0″
24. Clay slate, ...		
25. *Ninth vein of coal*, not proved, ...		
26. Slate, ...	98′	11″
27. Variable beds of sandstone, not explored, ...		
28. Strata, obscured by alluvium, and by large bloeks of grit stone, millstone, or pudding stone, . . . Some weak sandy ore occurs near the bottom, . .	75′	10″
29. Unexplored ground, chiefly soft, slaty rock, and micaceous sandstone beds, ...	37′	5″
30. Courses of small ironstone balls, in loose argillaceous rock, ...	5′	0″
Total vertical section, from the summit of Bear Hill, at $1\frac{1}{4}$ miles up the Creek, to its junction with the Tioga River, ...	523′	0″

The heights in feet above Blossburg in this and the following sections, are leveled from a point at Blossburg Bridge.

NOTE.—The chief supply of coal for the neighboring country has heretofore been taken from the 5th vein, No. 14. A lower vein of good quality has been recently opened.

The intersection of the principal coal beds in this ravine occurs at the distance of $1\frac{1}{2}$ miles, in nearly a straight line west from Blossburg Furnace.

Height of the highest coal bed discovered, 470 feet.

Height of the highest ore bed, 420 feet.

Towards the summit a considerable inclination of the strata occurs to the south and south-east, probably to the amount of 80 to 100 feet in a mile; nearer the base the beds are more horizontal.

3. Coal Run Section.

***Height of** Coal run, or table land, one and a half miles above coal openings.*

1.	Series of soft sandstone beds, indicative of coal. Thickness from the summit of mountain, opposite to the first or highest trial for coal, to that bed, by leveling,	128′	0″
2.	Blue clay slate, with vegetable impressions therein, .	3′	0″
3.	*First coal vein;* thickness uncertain at the outcrop.		
4.	Coal measures, with nodules of iron ore, ...	6′	0″
5.	Course of balls of *iron ore* in clay and shale, with impressions of ferns and reeds, 1.8′ to 2.8′, ...	2′	0″
6.	*Second coal vein*, showing 2′ at the outcrop, ...	2′	0′
7.	Argillaceous shale and clay, ...	4′	0″
8.	Dark blue sandy clay rock, having vegetable impressions and specks of mica therein, ...	6′	0″
9.	*Third coal vein*, not proved; at the outcrop only, . .	2′	0″
10.	Horizontal beds of clay and shale, ...	13′	5″
11.	*Fourth coal vein*, showing 18 inches face at the outcrop (this is probably the vein No. 10 in Bear creek—there 3.25 feet,)	1′	6″
12.	Bed of good fireclay, ...	2′	6″
13.	Dark laminated shale, ...	4′	0″
14.	Balls of *iron ore* in shale, occasionally very large, . .	2′	10″
15.	*Fifth coal vein*, now worked, from . . . . . 3′ 7″ to	3′	11″
16.	Bed of *fireclay*, dug with the coal, ...	2′	7″
17.	Argillaceous shale with occasional nodules of *iron ore*,	10′	1″
18.	Vein of *rock iron stone*, worked out a few feet on trial,	1′	4″
19.	Compact sandstone rock, ...	10′	4″
20.	Second vein of *rock iron ore*, ...	1′	0″
21.	Hard irregular sandstone, traversed by numerous thin seams of coal and vegetable impressions, ...	11′	7″
22.	*Sixth coal vein*, worked about 20 feet, divided by a seam of hard black slate 10 inches thick, ...	2′	8″
23.	Blue shaly argillaceous rock, ... / Horizontal beds of gray slaty sandstone, ... / Good compact building stone, ...	24′	7″

24. Course of nodules of *iron ore*, in blue clay,	2′	0″
25. Bed of *fireclay*,	3′	0″
26. *Seventh coal vein*, very pure and highly inflammable, 1 to 2 feet thick, but has not been pursued,	1′	0″
27. Course of *iron ore*, called pins or kidney shaped nodules,	1′	6″
28. Beds of shale and slate, irregularly disposed with occasional ironstone nodules,	22′	4″
29. *Eighth coal vein*, called cannel coal, not worked or examined, say,	2′	0″
30. Sandstone rocks and unexplored ground, down to level of springs, which probably issue from some mineral bed,	32′	6″
31. Unexamined ground, covered with alluvium and siliceous blocks; it consists chiefly of sandstone rocks like the preceding,	44′	4″
32. A thick bed or deposit of red, semi-indurated clay, containing a considerable weight of oxide of iron,	45′	8″
33. Continuation of similar ferruginous clay, altogether about 100 feet thick, as exposed on the slopes of the hill,	41′	10″
34. Lower part obscured by alluvial clay and stones,	10′	8″
35. Bed of weak, sandy, nodular iron ore, under the furnace,	2′	0″
36. Thence to the low water surface of the Tioga river, opposite to the iron furnace at Blossburg,	1′	1″
Total vertical elevation above the Tioga river,	455′	3″

NOTE.—Coal traces at this elevation of 500 feet above Blossburg Bridge; the ground rises beyond, 100 to 200 feet.

A considerable quantity of coal for the supply of the neighborhood has been taken from the colliery worked in the vein No. 5.

About 350 tons of the iron ore has been collected from the Bed No. 27, and is in readiness for smelting.

No other ore in the different beds in any of the sections has yet been raised.

The highest explored coal vein in this section is 320 feet vertical above the Furnace, and it is seven-eighths of a mile distance to the intersection of that vein on Coal Run; consequently the inclination of the plane is 36.5 feet per mile.

4. Morris Run Section.

1. Estimated height of strata belonging to the Coal formation, 600 feet.			
2.	[Concealed measures,]	140′	0″
	Coal veins at least one mile above the big vein.		

3.	[Concealed measures,]	50′	0″
	Shale and mineral beds unexplored.		
4.	[Concealed measures,]	30′	0″
	Coal vein, not proved.		
5.	Slaty rock and dark blue clay stone,	9′	0″
6.	Five or six courses of rich argillaceous ball ore, in large oblong masses,	5′	0″
7.	Black shale,	22′	0″
8.	Courses of good iron ore.		
9.	Black shale and slaty rock,	21′	0″
10.	Fireclay,	1′	0″
11.	Big vein of coal, clear thickness of upper part, 5′ 11″	6′	8″
	Small seam of slate, 0′ 2″		
	Lower part of the vein, 0′ 7″		
12.	Blue argillaceous shale,	7′	7″
13.	Coal vein, thickness not proved.		
14.	Yellow sandstone in thin beds.		
	The "Devil's Punchbowl,"	9′	0″
15.	Thin ledges of sandstone; head of the Falls.		
16.	Stratified bed of millstone grit, or pudding stone, in the bed of the creek traversed, 164 yards long, falls 18 feet,	16	0″
17.	Sandstone ledges at Falls,	51′	6″
	Strong mineral spring 5′ above bottom layer.		
	Two mineral springs on bottom layer.		
18.	Sandstone ledges, dipping S. and W.,	12′	6″
19.	[Concealed measures,]	17′	0″
	Traces of soft coal and of ore washed down the run.		
20.	[Concealed measures,]	16′	6″
	Masses of iron ore loose.		
21.	Sandstone beds or ledges dipping N. in creek.		
22.	Ledges of brown or ferruginous sandstone dipping North,	42′	0″
23.	Ferruginous sandstone,	67′	0″
	Mineral spring 35 feet above bottom of layer.		
24.	Siliceous ore in large balls, washed, about	10′	0″
25.	[Concealed measures,]	20′	0″
	Clay deposit, and masses of ore 30′ to 60′,	60′	0″
	Total of this section,	613′	9″

NOTE.—The only bed which has been examined in this section, is the big vein. No road at present exists to communicate with this valley.

A ravine which descends into this valley from the east, intersects both coal and iron beds.

5. Boon's Creek Section.

Commencing on the Mountain Flat.

1.	Sandstone beds appertaining to the coal series about 50 feet to the upper or first coal vein,	50′	0″

2. *First coal vein*, thickness uncertain and not explored,	15′	0″
3. Argillaceous shale, with traces of *iron ore*,		
4. *Second coal bed*, apparently a thick bed,	14′	0″
5. *Fireclay*, a thick bed,		
6. Shaly argillaceous rock,		
7. *Third coal vein*, below the narrows,	7′	6″
8. Several courses of good strong iron ore in balls,		
9. Rock or shale, uncertain.		
10. *Fourth coal vein*, of good quality, formerly opened by Mr. Bloss, and discontinued since the discovery of coal in more convenient situations,	8′	8″
11. Soft blue shale,	9′	7″
12. *Fifth coal vein*, also formerly opened by Mr. Bloss, of good quality,		
13. Blue shale,	3′	0″
14. Fireclay,	2′	0″
15. Sandstone rock and slate,	20′	3″
16. Compact sandstone and building stone to the head of the falls, probably a continuation of bed No. 23 in the Coal Run section, and in No. 12 of East Creek section,	16′	6″
17. Hard compact sandstone beds to the foot of the falls,	31′	3″
18. Various strata of sandstone, partially exposed; but for the most part concealed by very large masses and blocks of siliceous grit and pudding stone, extending down to the level of the Tioga River, about 200 feet lower. Many of these fragments, which have evidently sunk from a much higher elevation, contain more than a thousand cubic feet each,	200′	0″
Total of the section in vertical height above the Tioga River at Blossburg,	379′	9″

NOTE.—The intersection of the upper coal beds in this ravine is at the distance of 1½ miles in a straight line west from Blossburg Furnace.

Inclination 252 feet per mile.

6. Johnson Creek Section.

The intervals between, and the respective thicknesses of the different strata, are for the greater part by estimation only in this section.

The present section commences at 5 miles S. W. of Blossburg.

Bed of bog ore near the summit 3′ thick.

First coal bed from 50 to 70 feet above No. 3.

1. Grey shale and slate, with indications of coal, may be traced toward the upper part of the creek, and continues to a strong ferruginous spring, with appearances of bog ore.		
2. Courses of good *iron ore*, in flat masses, bedded in shale and slate,	2′	0″
3. *Second coal vein*, showing a face of 18 inches in the bank of the creek,	1′	6″
4. *Fireclay*, about 18 inches,	1′	6″
5. Alternate beds of shale or slate and clay, with nodules of iron ore interspersed, estimated at	10′	0″
6. Fireclay,	1′	6″
7. *Third coal vein*, about 18 inches face, in the bank,	1′	6″
8. Soft rotten slate,	2′	0″
9. Thick bed of *argillaceous* iron ore, occurring in masses, both as veins and balls,	3′	0″
10. Slate as before extending to another or two courses of good *iron ore*, in large slabs and flat balls 10 or 12 inches thick, 12′ to 15′,	15′	0″
11. Dark colored slaty beds as before, with courses of iron balls as before, at intervals of 60 to 80 feet,	70′	0″
12. Shale or slate, with more balls of iron ore,	20′	0″
13. Slate again, with seams and flattened masses and balls of iron ore,	15′	0″
14. Slate continued, to a spring of strong chalybeate or ferruginous water,	20′	0″
15. *Fourth coal bed*, of an extremely hard quality, called splint coal, 10 inches,	4′	0″
16. Black shale bed intermediate, 14 inches,		
17. *Fifth coal bed*, very hard, like the first bed, and partially resembling the cannel coal and that in bed No. 29 of Coal Run, 2 feet,		
18. Dark shale and rotten or shivery argillaceous slate,	6′	0″
19. *Sixth coal vein*, a small bed, showing only 4 inches thick on the face of the hill.		
20. Below the vein, slate of a similar quality continues many feet.		
Total,	173′	00″

NOTE.—It will be perceived that the great characteristic distinction of this section is the prevalence and vast thickness of slate. Instead of the intermixed series of siliceous sandstones and argillaceous shales, as in the foregoing examples, we have here a vast mass of slate, at least 250 feet thick, comprising within it the subordinate series of coal and iron seams.

No opening having been made in any of these beds of coal, except a few inches, a fair estimate either of quality

or thickness cannot yet be obtained, and they can only be regarded as specimens of surface coal.

From the extreme hardness of the lower beds of coal it is probable that they are not greatly affected by atmospheric agency even at the outcrop.

7. Tioga Valley Section.

Height of strata at 7½ miles by estimation above Blossburg:

1. Hard yellow sandstone.		
Traces of coal and iron ore washed in the creek,	18′	0″
Yellow laminated sandstone	16′	0″
Hard ferruginous sandstone,		
2. Red shale, with shells at fork,	2′	0″
3. Conglomerated sandstone and green shale,	4′	0″
4. Red argillaceous shale,	2′	0″
Sliding bank with coal and iron ore fragments washed down.		
5. Yellow sandstone, laminated beds,	23′	0″
6. Green and red argillaceous shale,	30′	0″
7. Unexamined ground, on account of the alluvium and gravel,		
Shale fragments,		
8. Sliding bank, with much coal and coal shale,	10′	0″
Yellow shalo and claystone fragments,		
Hard brown sandstone, horizontal,		
Loose cannel coal, in fragments, washed,		
9. Sandstones,	24′	6″
Fishing Camp,		
Mouth of Fellow's Creek,		
Laminated sandstone,		
10. Alternating beds of red argillaceous slate, and laminated sandstone,	7	6″
11. Blue slate,	3′	0″
Fragments of hard or splint coal.		
12. Fine laminated gray flagstone,	12′	7″
13. Fino whetstone bed,	10′	0″
14. Argillaceous flagstones,	13′	0″
Pyramid rock in river,		
15. Obscure strata, chiefly sandstone,	16′	0″
Loose balls of ore,		
Fragments of cannel coal,		
Masses of fine argillaceous iron ore,		
16. Sandstone beds, dipping North,	13′	0″
Big gritstone rock in river, 94 tons,		
17. Ferruginous sandstone,	10′	0″
18. Horizontal strata,		

19. Siliceous ore in large masses and balls, loose, ... Big Pine tree, ...	15′	0″
20. Sandstone, obscure, ... Fork of Morris Run, ...	17′	0″
21. Sandstones, dipping West, ...	13′	5″
22. Clay deposit, with ferruginous nodules . . . . . Level of Blossburg bridge, ...	34′	0′
Total, ...	304′	0″

NOTE.—The Tioga above the narrows passes through wide bottoms and alluvial flats, and does not wash the banks so as to show the mineral or other strata. These beds are therefore imperfectly ascertained, and would require further time to be investigated satisfactorily.

The levels were ascertained by instruments to the height of 216.83 feet, beyond that point the elevations were merely by estimation.

8. Fellow's Creek Section.

1. Rise of ground to summit flat, estimated at 260 feet above last observation. Chiefly sandstone series of the coal measures, . . .	200′	0″
2. Sandstone beds at 7½ miles N. E. from Blossburg. Deer Lick above Fellow's falls. Top of upper falls and of puddingstone strata. Bottom of upper falls, in ledges.		
3. Thickness of conglomerate gritstone or puddingstone.	60′	0′
Top of second fall. Bottom, perpendicular. Top of lower or 3d fall, puddingstone ledges, dipping west, ...	17′	0″
4. Sandstone ledges, ... Deep basin or trout hole, 8 feet deep, ...	8′	0″
5. Argillaceous shale, ... Bottom of lower falls.	8′	0′
6. Yellow sandstone ledges, ... Coal slate washed in creek, ... Course of creek, N. E., ...	12′	0″
7. Sandstone beds and strong mineral spring. Little run from the west, with coal slate, probably washed at least 150 feet down, ... Traces of soft bituminous coal in east bank, ...	20′	0″
8. Argillaceous beds, ... Mineral spring, and bed of iron ore in seams, ... Argillaceous strata, ...	30′	0″
9. Iron ore masses, loose in creek, ... Small run from the west containing coal fragments at 80 to 100 feet up, ...	20′	0″

10. Ground obscured by alluvium, gravel and vegetation, Coal fragments in creek, Cannel coal fragments in the creek, Coal traces,	29′	0″
11. Strata doubtful, but apparently chiefly argillaceous, Mineral spring, Iron ore balls, washed, Ledge of argillaceous rock, 5 feet, Little Fall,	29′	0″
12. Argillaceous strata, Loose iron ore masses, Fishing camp at Forks, Fork of Tioga and Fellow's Creek,	42′	0″
13. Sandstone, laminated beds,	38′	0″
14. Argillaceous rocks, flagstones, whetstones and shales, Coal and iron ore at various elevations washed,	137′	0″
15. Sandstone series, To level of Blossburg bridge,		
Total,	650′	0″

NOTE.—The central part of this section is almost entirely obscured by alluvial matter, and few opportunities exist of exploring the hillsides, consequently, the single exploration that has been made is by no means complete.

The levels were taken by instrument $5\frac{1}{4}$ miles from Blossburg; beyond this, the upper part was finished in part by estimation and partly by admeasurement.

The three falls in this creek have a descent of about one hundred feet in an eighth part of a mile, where the beds of hard conglomerate gritstone have checked the erosion of the channel, as in the case of most of the other ravines. At this point the creek is limited to a narrow gorge or chasm, in one place only twelve feet wide, having its edges rise almost perpendicular to the height of from 80 to 100 feet. Near the foot of the second fall is another which is precipitated from the east cliff about 65 feet, over the entire mass of conglomerate. On ascending the bed of this eastern stream, above the fall, traces of coal were abundantly discovered.

Argillaceous Iron Ore

Occurs in numerous beds under different forms and of variable qualities, interstratified with the coal, clay and slate beds. In form, they comprehend the three varieties known

to most English and to all Welsh miners by the distinctive terms of *veins*, or continuous parallel seams; *pins*, or small nodular kidney shaped concretions; and *balls*, or larger, detached, oval, flattened masses, from 1 to 4 feet long, sometimes irregularly interspersed, but more often occurring in horizontal *courses*. Those of the first mentioned form are the least, and of the third description, the most prevalent in the district under investigation.

In point of quality, the pins or kidney shaped ores are somewhat the weakest, the veins are the most siliceous and most difficult to be fluxed, and the balls are commonly the richest, and the easiest or most profitable to convert into iron; and without entering into analysis, both the balls and kidney ores may be stated as fully equalling the similar argillaceous ores from whence the foreign iron imported into this country is derived.

With regard to quantity or amount—a material question undoubtedly—this mineral, although abundant in the aggregate, is not in all cases so conveniently circumstanced for mining, as the most economical system of working might require. Yet in all the ravines there are positions where the courses are sufficiently contiguous to be excavated to advantage.

With the exception of a few small openings, on trial for this mineral, so little has been heretofore attempted to exhibit the positive amount procurable from any mine, or in any particular bed, that calculations can only be made with safety or precision, after the investigation shall have been pursued on a larger and more practical scale than the writer was at liberty to do. In Bear Creek two sections are exposed in which are several courses of good ore in balls, which would yield a considerable supply for a furnace. Coal Run intersects iron ore beds in eight or nine different positions. Besides various courses of ball mine, here are two seams, of a siliceous or gritty ore, and the kidney variety, or pins, of which about 350 tons have been raised with the intention of smelting, as soon as the furnace is completed. The specific gravity of the kidney ore, averages 3.411, its weight per cubic foot, 211 pounds, and the

gross produce or weight per acre, 1 foot thick, is 4.122 tons. Any of these beds can be worked with ease by means of horizontal drifts or levels. In the lower part of this ravine is a thick deposit, peculiar to this locality, of a red semi-indurated clay, containing an admixture of oxide of iron. Its specific gravity is 2.514, but it is too poor to be worked for the ore.

A deposit of clay occurs in the hill side, three quarters of a mile up the Tioga, and probably is an extension of this bed. It contains masses of argillaceous iron ore. This is at only 30 feet above our common base. The siliceous or sandy ore of Coal Run, contains a considerable admixture of iron; its weight being about 200 pounds to each cubic foot. One vein is from 15 to 18 inches thick, and another is somewhat less.

Large masses of siliceous ore are found in the Tioga at elevations of not more than 60 to 80 feet, and it is probable that a considerable bed of it exists about two miles above Blossburg in the rocks bordering the river.

Slabs of argillaceous ore were discovered in Taylor's Creek, at different elevations, about 4 miles south of Blossburg; also in Fellow's Creek, 5 or 6 miles to the northeast.

Our section of Boon's Creek, bed No. 8, shows some courses of excellent balls of ore, which might conveniently be worked with the superincumbent coal vein No. 7.

Johnson's Creek may be remarked for the numerous courses of this mineral, occurring at irregular intervals, throughout a thickness of more than 200 feet of slate and shale. Beds No. 2 and 9 in that section, contain several courses of flat balls and tabular masses, ten or twelve inches thick, of strong rich ore; some of them containing three cubic feet, and weighing six hundred weight. Specific gravity 3.999, weight per cubic foot, 250 pounds, and yielding 4,850 tons per acre for every foot in thickness.

One of the richest beds of ball mine occurs in Morris' Run, section No. 4, consisting of five or six courses, some of the balls being three or four feet long, and upwards.

Specific gravity of this ore,	3.440
Weight per cubic foot,	215 lbs
Weight per acre, for each foot,	4.200 tons

The clear produce of this bed may be estimated at more than five thousand tons per acre. There is no reason to conceive, on comparing the sections of various ravines, that all these deposits are co-extensive with the entire coal region.

The highest position at which I have discovered good ball ore is at the height of 420 feet above the Tioga, toward the summit of Bear Creek, and the lowest is about 180 feet above the same river at Coal Run; so that here also is a range of about 240 feet, containing beds of iron ore.

Pipe ore in small quantities has been met with near Johnson's Creek.

Bog ore occurs sparingly except at a few points, which have not been very satisfactorily explored. At the summit of Johnson's Creek is a bed of this description of ore three feet thick."

It is not necessary to reproduce in detail Mr. Taylor's description of the character and quality of the Blossburg coal, inasmuch as all his information on the subject, which was necessarily limited, is embraced in the mass of information on that subject which is given in the detailed chapter describing the various mining operations in the basin, and more especially and fully in the chapter on the character and condition of the Blossburg Coal.

Mr. Taylor's information concerning the coals and iron ores is summed up in the following table:

The following table represents the comparative specific gravity, cubical contents, weight and gross produce per acre of the principal varieties of coal, iron and stone referred to in the foregoing article:

Coal.	Specific gravity.	Weight of one cubic yard.			Thickness of the vein.	Gross contents or weight per acre of each vein.
		Tons.	Cwt.	Lbs.	Feet.	Tons.
Knap's Coal in Coal Run, . . .	1.367	1	0	60		
Knap's Coal in Coal Run, 2d experiment—select and pure,	1.371	1	0	73	3.75	6,252
Knap's Coal in Coal Run, 3d experiment—rather slaty, . .	1.400	1	1	10		
Clement's Coal in Bear Creek, average, ...	1.398	1	1	7	3.25	5,530
Bloss Coal in Bear Creek, lighter part of vein, ...	1.378	1	0	85		
Bloss Coal, in Bear Creek, heavier part of same vein, .	1.432	1	1	64	3.00 to 3.25	5,123
Bloss Coal in Bear Creek, average of the coal, ...	1.405	1	1	19		
Johnson's Creek, Splint Coal, two veins, ...	1.493	1	2	55	3.00	5,442
Cannel Coal in Coal Run, at the cross, ...	1.716	1	5	96		
Cannel Coal of the purest quality, ...	1.750	1	6	41		
Big Vein in Morris Run, by estimation, ...	. . .	. . .	. . .	. . . .	6.50	10,652
Little Vein of very pure inflammable coal in Coal Run, under the Kidney Ore, . . .	1.500	1	2	65	1.25	2,115
Limestone from Limestone Hill, ...	2.667	2	0	20		
Coarse grained, Millstone Grit,	2.505	1	17	83		
Fine Siliceous rock, or petrosilex, locally called marble, .	2.703	2	0	81		
Red ferruginous clay of Coal Run, ...	2.514					

Argillaceous Iron Ore.	Specific gravity.	Weight of one cubic foot.		Weight of one foot thick per acre.
		Cut.	Lbs.	
Weak ball ore, on surface, below Clement's coal,	3.047	1	78	3,694
Kidney shaped ore, or pins, raised for furnace,	3.400	1	98	4,083
Second experiment,	3.423	1	102	4,161
Average,	3.412	1	100	4,122
Ball ore in the bed of Bear Creek, 42 feet above the Tioga River,	3.212	1	89	3,908
Ball ore in large masses at Morris' Run,	3.440	1	103	4,200
Ball ore in rich nodules at Johnson's Creek,	3.999	2	26	4,852
Vein of siliceous or sandy ore in Coal Run, fine grained,	3.135	1	86	3,850
Second experiment, coarse grained,	3.196			

Report of the First Pennsylvania Survey.

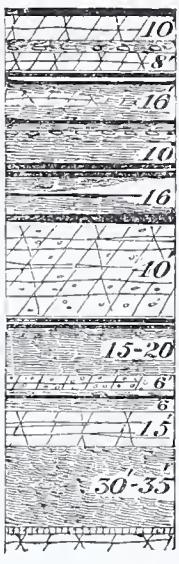
At the time when the report on the Blossburg Coal Basin was made for the First Geological Survey of Pennsylvania, the region just around Blossburg was being actively worked, and a perfect section was obtained and published; and also some complete sections on Morris Run, Coal Run, and Bear Creek.

These sections, in conjunction with those given on the preceding and succeeding pages, make a very accurate record of the measures of the basin, the sections reproduced from the Final Report being made at different points in the basin, and in some cases, as at Blossburg, in places where a section is not now obtainable in such complete detail, owing to abandonment of workings; while the sections now for the first time produced are constructed from actual shaftings and borings at workings which did not then exist.

The First Survey thus reported the vertical section of the measures on Morris Run, as furnished by Mr. Young:*

* Final Report of Penn'a, Vol. II, p. 519.

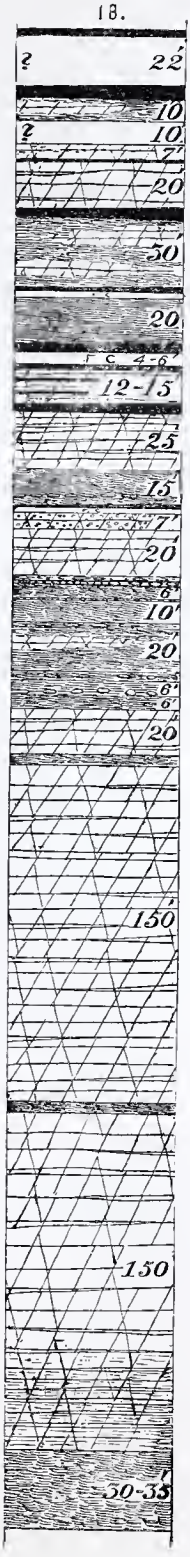
17.



Coal, all good,	4′ 0″
Sandstone, somewhat pebbly,	8′ to 10′ 0″
Shales, with balls of iron ore,	4′ to 5′ 0″
White and gray sandstone,	6′ to 8′ 0″
Bituminous slate,	1′ 3″
Coal,	1′ 5″
Bituminous slate,	2′ 6″
Coal,	0′ 2″
Slate and sandstone,	16′ 0″
Coal, resting on fireclay,	1′ 4″
Slate,	3′ 6″
Slate, with balls of ore,	4′ 0
Strong slate,	10′ 0″
Coal, in two benches,	5′ 6″ to 6′ 0″
Slate and fireclay, with 8 inches of *coal* in the middle,	16′ 0″
Coal,	3′ to 5′ 0″
Pebbly sandstone,	40′ 0″
Shale,	1′ 0″
Coal,	1′ 4′ to 1′ 6″
Slate,	1′ 0″
Coal,	1′ 3″
Slate,	15′ to 20′ 0″
Conglomerate,	6′ 0″
Iron shale, with very little ore,	3′ 0″
Coal,	0′ 10″
Clay slate,	6′ 0″
Green sandstone,	15′ 0″
Red shale, or marl,	30′ to 35′ 0″
Sandstone, with 3 feet of sandy limestone,	
Total,	224′ 3″

The vertical section of the measures at Blossburg is given in the Final Report, as furnished by the Messrs. Evans, as follows:*

* Final Report of Penn'a. Vol. II, p. 520.

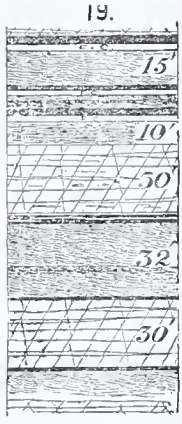


Coal, all good,		3 6″
Space,	22′	22′ 0″
Coal, 3′ 6″ good,		4′ 6″ to 5′ 0″
Slate and sandstone,	10′	10′ 0″
Blank, about	?	10′ 0″
Pebbly sandstone,	10′	10′ 0″
Coal,	7″	7″ 0″
Sandstone,	20′	0′ 10″
		20′ 0″
Coal, dirty,		2′ to 5′ 0″
Slate and sandstone,	50′	30′ 0″
Coal,		1′ 3″ to 1′ 6″
Fireclay,		3′ 0″
Slate,		20′ 0″
Coal, 3′ good, the Morris bed,	20′	3′ 6″
Fireclay,	P. C. 4-6′	4′ to 6′ 0″
Coal,		2′ 0″
Argillaceous sandstone and slate, with two thin coals,	12-15′	12′ to 15′ 0″
Coal, thickest at Bear Creek,	25′	3′ to 4′ 0″
Micaceous sandstone, thin bedded,		25′ 0″
Shale, with 1′ kidney ore,	15′	15′ 0″
Coal, Kidney bed,		4″ to 1′ 6″
Impure fireclay,	7′	2′ 0″
Pea Conglomerate,		7′ 0″
White sandstone, in part suitable for making glass,	20′	20′ 0″
Total,		238′ 10″
The measures below the coal are given as follows,	6′	joining on to the bottom of the above section
Shales, with lean Oolitic ore,	10′	1′ 6″
Ore,		1′ 6″ to 2′ 0″
Red and mottled shale,	20′	6′ 0″
Ore,		0′ 6″
Shale,		10′ 0″
Shale, with coarse nodular ore,		2′ 0″
Argillaceous sandstone and slate,	6′	20′ 0″
Shale, with 1′ 6″ of gray ore,	6′	4′ 0″
Slate, with 7″ of ore,		6′ 0″
Slate,	20′	6′ 0″
Dark-brown micaceous sandstone,		20′ 0″
Red shale and green slate,		5′ 0″
Greenish-gray sandstone to level of railroad	150′	150′ 0″
Red shale, about		4′ to 5′ 0″
Vespertine sandstone, calcareous bed about 30 feet from bottom,	150′	150′ 0″
Red shale and marl,	50-35′	30′ to 35′ 0″
Green flaggy sandstone,		—
Total,		423′ 0″

The following section exhibits the alternation of Vespertine and Ponent strata, displayed at Blossburg:*

Brown conerctionary calcareous Conglomerate,	0′ 0″
Grcenish grey flaggy sandstone,	20′ 0″
Brcceiated or lower calcareous Conglomerate,	1′ to 4′ 0″
Greenish and bluish grey micaccous sandstone,	20′ 0″
Red marl, streaked with blue blotehes,	10′ 0″
Red marly shale,	30′ 0″
Grey mieaceous sandy slatc,	2′ 0″
Grcenish grey micaceous sandstone,	0′ 0″
Total,	86′ 0″

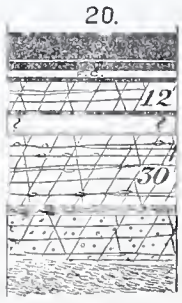
The vertical section of the measures showing on Coal Run is thus given:†



Brown sandstone, with kidney ore shut out by the sandstone; shelly, thin,	
Coal, chiefly eannel,	3′ 0″
Firecla y,	2′ 6″
Shale,	15′ 0″
Coal, (the fircelay coal,)	1′ 6″
Firecla y,	2′ 6″
Shale,	2′ 0″
Nodular ore band,	0′ 4″
Shale,	3′ 0″
Coal, (the Morris bed,)	3′ 6″
Firecla y,	2′ 6″
Slate,	10′ 0″
Sandstone, vegetable remains,	30′ 0″
Firecla y,	0′ 6″
Coal, cannel, (including two scams of slate, 12 and 3 inches thick,)	3′ 10″
Shale, with rich kidney ore, (aggregate thickness 6 inches in 3 feet of shale,	32′ 0″
Coal, too far below the orc to be worked with it; this is the kidney eoal,	1′ 0″
Sandstone,	30′ 0″
Coal, eannel,	2′ 0″
Olive shales, thickness unknown,	
Sandstone, with vegetable remains passing downwards into Conglomerate,	
Total,	145′ 2″

Then the Vespertine red shales are seen alternating with sandstone strata.

The vertical section of the measures in Bear Creek is given as follows:†



Coal, variable, sometimes 1 foot shale, embraeing 4 inehcs of iron ore,	10 to 12′ 0″
Coal,	3′ 7″
Firecla y,	2′ to 3′ 0″
Coal, lower half eannel,	1′ 2″
Dark sandstone,	12′ 0″
Coal,	1′ 6″
Interval,	
Sandstone, imbedding pebbles,	30′ 6″
Shale, containing iron ore,	3′ to 4′ 0″
Sandstone, conglomerate,	
Umbral shales,	
Total,	67′ 3″

The upper coal occurs on the south side of the creek,

* Final Report of Penn'a, Vol. II, p. 522.

† Final Report of Penn'a, Vol. II, p. 521.

where it is 1 foot 6 inches thick, but on the north side it is entirely wanting.

The ore in the next stratum is good, but small in quantity; the bed is also visible in Coal Run.

The next bed is the main coal seam of Blossburg; it has been opened in five different drifts, two on the south side and three on the north side of the creek, at an elevation of about 280 feet above the railroad, not quite a mile distant. The quality of this coal is somewhat injured by the amount of sulphuret of iron occasionally present, from which, however, the chief part of the bed is comparatively free, having a fine brilliant lustre. A fault, crossing the three drifts on the north side of the creek in a N. E. and S. W. course, throws down the coal 3 feet. The fireclay under this coal contains *Stigmaria ficoides*. At its outcrop occurs large deposit of exceedingly tough clay derived from this bed, well adapted for the manufacture of fire bricks.

The 18 inch seam of coal has been partially mined. The sandstone which underlies it is rather remarkable. passing in its lower bed into a coarse conglomerate.

Under the latter lies another sandstone, and beneath that the Umbral Red Shale.

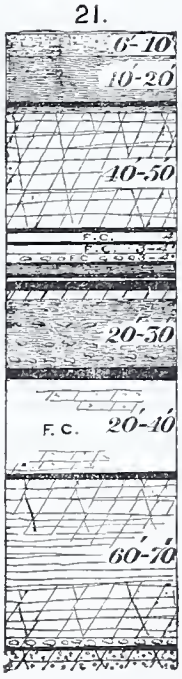
Beneath the Seral Conglomerate a band of iron ore was struck, which upon being pursued into the hill, thinned entirely away. Its appearance justifies further exploration.

The shale containing this ore is nearly 5 feet thick; at its outcrop the ore consists largely of long elliptical balls of a very argillaceous brown ore, lying closely adjacent to each other, and forming more than one-half of the stratum. Each elongated nodule exhibits externally a series of concentric crusts, which readily peel off by exposure to the atmosphere. Beneath the balls lies a nearly solid layer of a heavy yellowish-gray ore, about 6 inches thick, having a true oolitic structure. These beds appear to be shut out by the overhanging sandstone at a short distance from the surface. Other excavations have been made for ore in the other red bands lower down in the series, but unsuccessfully. The conglomerate and sandstone of the two beds described, strew the hill-sides in great quantity, and furnish an excellent building material."

Fall Brook Mines.

The most eastern and northern part of the Blossburg Coal Basin, where extensive development of the coal has been made, is at Fall Brook. Here the Fall Brook Coal Company have been mining on a large scale for years, and have a very costly and complete plant, including mines, coal dumps, railroad, and a well built village. The mines are 1842 feet above tide. The railroad from Blossburg to Fall Brook is eight miles in length.

The complete vertical section of the measures at Fall Brook is thus given by Mr. Hardt, chief engineer of the company, compiled from old shaft openings, borings, &c.:



Surface,	—
Loose drift,	6′ to 10′ 0″
Black slate,	10′ to 20′ 0″
Coal, (Seymour or Cushing Vein,)	2′ 8″
Black and gray slate,	3′ 0″
Sandstone,	40′ to 50′ 0″
Coal, (Morgan or Dirty Vein,)	2′ 0″
Fireclay and Bastard,	4′ 0″
Coal,	0′ 8″
Fireclay,	3′ to 4′ 0″
Fireclay, (with iron ore balls,)	3′ to 4′ 0″
Coal,	0′ 6″ to 1′ 0″
Black slate,	3′ to 1′ 0″
Coal,	1′ to 2′ 0″
Gray slate,	0′ 6″ to 1′ 0″
Coal,	1′ 0″
Bony *coal*,	0′ 8″
Coal,	1′ to 2′ 0″
Sandrock,	2′ to 4′ 0″
Gray and black slate, (with iron ore balls,)	20′ to 30′ 0″
Coal, (Bloss Vein,)	3′ to 5′ 0″
Bastard fireclay and rock mixed,	20′ to 40′ 0″
Coal, (Bear Creek,)	2′ to 3′ 0″
Bastard rock and sandstone,	60′ to 70′ 0″
Kidney ore balls and slate,	1′ to 3′ 0″
Coal, (Kidney Vein,)	1′ to 2′ 0″
Conglomerate sandstone rock,	—
Total,	269′ 0″

The section at Fall Brook, as compiled by myself, with the assistance of Mr. Pollock, chief miner, varies slightly from the above. It is as follows:

Surface,	—
Dark-blue sandy slate,	9′ 0″
Bluish slate, (iron ore in thin flakes,)	10′ 0′
Coal, Seymour Vein, not worked,	2′ 6″
Rough, sandy, impure fireclay,	2′ 0′
Sandstone, thin bedded usually, much current bedded, with numerous thin conglomerate layers, small, white, round pebbles, called "Monkey Ledge,"	40′ to 60′ 0″

Slaty *coal*, and fireclay, "Monkey vein," worthless at this place,	3′ 0″
Dark-blue slate, (ore balls,)	8′ 0″
Coal, small,	0′ 6″
Dark-blue slate,	6′ 0″
Coal, small,	0′ 6″
Dark-blue slate,	6′ 0″
Coal, "Dirty Vein," { Coal, 2′ 0″ / Slate, 1′ 3″ }	3′ 3″
Rough, hard fireclay,	2′ 0″
Gray, shaly rock,	20′ 0″
(Place of "Fireclay coal bed," wanting at Fall Brook.)	
Fireclay, kidney ore on bottom,	2′ 0″
Compact, light-gray S. S.,	9′ 0″
Clay slate,	0′ to 5′ 0″
Coal, (Bloss Vein,)	4′ 0″
Fireclay, sometimes pure and valuable,	3′ 0″
Sandy slate, some sandstone layers,	16 0″
Coal and slate, (Bear Creek,)	1′ 6″
Sandy clay, (some ore in bottom,)	4′ 0″
Reddish-brown sandstone,	25′ to 30′ 0″
Compact white sandstone,	18′ 0″
Conglomerate sandstone,	14′ 6″
Reddish, sandy shale,	9′ 0″
Slate, holding ore balls,	2′ 6″
Black slate and coal, (Kidney vein,)	1′ 0″
Sandstone,	—
Total,	251′ 1″

The Seymour (*or Cushing*) coal bed is only opened at Fall Brook on the outcrop for examination; no regular drift has been run in upon it, and no coal shipped from it to market.

A specimen of coal taken from the outcrop was forwarded for analysis, and yielded (A. S. McCreath):

The coal is very tender, bright, shining, with somewhat columnar structure and cubical fracture. It contains numerous thin partings of mineral charcoal and iron pyrites.

Water,	1.970
Volatile matter,	20.105
Fixed carbon,	68.360
Sulphur,	1.795
Ash,	7.770
	100.000
Coke, per cent.,	77.925
Color of ash,	Lilac.
Sulphur left in coke,	1.222
Per cent. sulphur in coke,	1.568
Per cent. of sulphur volatilized in coking,	31.92
Per cent. iron in coal,	.882

Sulphur taken up by iron,	1.007
Free sulphur,	.788

This analysis shows the Seymour bed at Fall Brook as of only medium quality, and with too high a percentage of sulphur; though in the last respect allowance must be made for an imperfect specimen, taken from outcrop, and not under sufficient cover. But the Bloss bed at Fall Brook has proved so large in size, so excellent in quality, and so economical in working, that the other beds of the measures have hitherto been neglected.

The sandstone which underlies the Seymour coal bed is one of the most marked and persistent features of the Blossburg Coal Basin. It is known in all the different localities as the "*Monkey Ledge;*" is from 40 to 60 feet thick, averaging 50 feet; is thin bedded usually, though with occasional massive plates, and is enormously current bedded, with numerous layers of conglomerate sandstone through the mass, scattered at no regular intervals, usually in thin plates, with white, rounded quartz pebbles. Always recognizable, and usually noticeable by making cliffs near the hill tops, it is the great mark and guide to the geology of the Basin.

The "*Monkey Coal*" bed has been drifted in upon by the Company, but never mined.

The coal is of fair quality, though somewhat more ashy than the others, but is so mixed with slate and dirt as to be worthless at this place.

A specimen of the coal yielded, on analysis: (A. S. McCreath.)

The coal has a dull, dirty appearance, being for the most part coated with infiltrated silt. On fresh fracture it shows bands of bright crystalline coal, and considerable slaty coal. It carries numerous thin partings of mineral charcoal and some iron pyrites.

Water,	1.560
Volatile matter,	20.740
Fixed carbon,	66.587
Sulphur,	.773
Ash,	10.340
	100.000
Coke, per cent.,	77.700
Color of ash,	Reddish gray.

This coal lies directly at the bottom of the "Monkey Ledge."

The "*Morgan or Dirty Vein*" of coal, lying under the "Monkey Vein," has been drifted into by the Fall Brook Coal Company, but never mined for shipment.

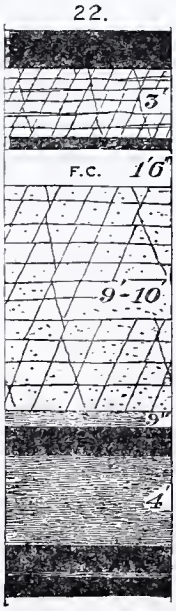
The coal of the bed is good, but is too much intermingled with dirt, clay, and slate to be economically worked out in in a clean condition for market.

A specimen of the coal yielded on analysis (A. S. McCreath):

The coal has a dull, dead lustre, being generally coated with silt. On fresh fracture, the coal is bright, crystalline, and columnar. It carries numerous thin partings of mineral charcoal, and some iron pyrites.

Water,	2.820
Volatile matter,	17.975
Fixed carbon,	71.326
Sulphur,	.634
Ash,	7.245
	100.000
Coke, per cent.,	79.205
Color of ash,	Reddish gray.

The measures between the "Monkey Vein" and "Morgan," or "Dirty Vein," were exposed in detail at one place, and showed as follows:



Sandstone,		
Coal, "Monkey Vein,"		1′ 8″
Sandstone, thin-bedded,		3′ 0″
Coal,		0′ 7″
Fireclay, variable, av'ge,		1′ 6″
Sandrock,		9′ to 10′ 0″
Slate, bluish,		0′ 9″
Coal, (not worked,)		1′ 3″
Slate, bluish,		4′ 0″
Coal,		1′ 2″
Slate,	"Dirty Vein,"	0′ 3″
Coal,		0′ 10″
Total,		25′ 0″

But the coals themselves, and the measures immediately enclosing them, are subject to rapid and serious changes, both in character and thickness.

The "*Fireclay Vein*" of coal is not found at Fall Brook; shale, holding balls of iron ore, occupying the place held by the Fireclay Vein at Arnot.

The next coal bed in descending order is the *Bloss* coal bed.

This is the most important bed of the Basin, and the one which has hitherto yielded almost all of the "Blossburg coal" shipped from the region.

At Fall Brook all the coal shipped to market, nearly two millions of tons, has come from the mines on this bed. The mines of the company are in most admirable order, and the plant is expensive and complete, embracing everything that a judicious development would call for.

The coal runs in thickness from three feet four inches to five feet; averaging four feet six inches. It has no regular parting slate in the No. 3 mine; but has parting slates where worked off to the north. This slate was 8 inches thick, in three layers, and with usually 6 inches of bottom coal under the lowest slate.

A specimen of the Fall Brook Bloss bed coal yielded on analysis (A. S. McCreath):

The specimen contains bright crystalline tender coal, with columnar structure and cubical fracture. Also, bright resinous, slaty, cannel-like coal, having a somewhat conchoidal fracture.

Water,	1.050
Volatile matter,	18.540
Fixed carbon,	69.934
Sulphur,	.661
Ash,	9.815
	100.000

Coke, per cent.,	80.41
Color of ash,	gray.
Sulphur left in coke,	.561
Per cent. sulphur in coke,	.696
Per cent. iron in coal,	.133
Sulphur taken up by iron,	.152
Free sulphur,	.409
Per cent. sulphur volatilized by coking,	15.12

This analysis represents a fair average specimen of run of mine coal as shipped in quantities to market.

A specimen of the crystalline coal, which runs in streaks through the Fall Brook Bloss coal bed, was analyzed separately, and yielded (A. S. McCreath):

Water,	1.000
Volatile matter,	20.830
Fixed carbon,	70.854
Sulphur,	.796
Ash,	6.520
	100.000
Coke, per cent.,	78.170
Color of ash,	gray.

The cannel-like coal yielded on separate analysis (A. S. McCreath):

Water,	1.200
Volatile matter,	17.110
Fixed carbon,	66.212
Sulphur,	.568
Ash,	14.910
	100.000
Coke, per cent.,	81.69
Color of ash,	gray.

In the cannel-like coal, the coke is only slightly coherent.

Mr. Pollock reports that the Bloss Vein in going north from mine No. 3 takes in more slate; and that to the north and north-east, a distance of from one to two miles away, the bed had run down to a thickness of nine inches.

The general average rise of the coal is to the south-east about 3′ in the 100′; the dip therefore being to the north-west.

Fall Brook village, however, is not exactly at the centre of the basin, or on the centre of the synclinal axis.

The *Bear Creek* coal bed has been opened up at Fall Brook by the company.

A well-timbered drift was put in on the coal, and continued far under perfect cover, but the bed never rose to a steady workable thickness. It is called one and a half feet to two feet thick, but will average more nearly one and a half feet than two feet in thickness.

The coal itself is good and firm, but contains more ash than the Bloss bed above it.

A specimen of the average run of the bed was analyzed at Harrisburg, and yielded (McCreath):

The specimen consists of bright crystalline columnar coal with numerous thin partings of mineral charcoal, and some iron pyrites; and compact resinous cannel-like coal having a conchoidal fracture.

Water,	.790
Volatile matter,	20.965
Fixed carbon,	65.465
Sulphur,	.725
Ash,	12.055
	100.000
Coke per cent.,	78.225
Color of ash,	gray.
Sulphur left in coke,	.526
Per cent. sulphur in coke,	.672
Per cent. iron in coal,	.245
Sulphur taken up by iron,	.280
Free sulphur,	.445
Per cent. sulphur volatilized by coking,	27.44

A specimen of the crystalline coal from the Bear Creek coal yielded on analysis (McCreath):

Water,	.770
Volatile matter,	22.180
Fixed carbon,	67.191
Sulphur,	.799
Ash,	9.060
	100.000
Coke per cent.,	77.050
Color of ash,	gray.

A specimen of the cannel-like coal from the Bear Creek coal yielded on analysis (McCreath):

Water,	.800
Volatile matter,	15.720
Fixed Carbon,	59.299
Sulphur,	.471
Ash,	23.710
	100.000
Coke, per cent.,	73.480
Color of ash,	Gray.

In the cannel-like coal the coke is only slightly coherent.

The *Kidney* coal bed at Fall Brook shows only 6 inches to 12 inches of coal and black slate; it is entirely worthless.

A micaceous slate overlying the coal holds numerous kidney iron ore balls; but while the balls are very numerous in places, yet there does not seem to be any regular and persistent plate of iron ore.

The ore balls are, as is usual with the Kidney balls, of excellent quality.

The massive sandstone which is between the Bear Creek and Kidney coal beds, about 60 feet thick, is made up of an upper layer, 35′ to 45′ thick, of massive gray sandstone, with numerous layers of pebble rock, of rounded, white quartz pebbles, usually not large; the rock stands out on massive cliffs and makes the falls at Fall Brook; and of a lower layer of about 20′ thick, usually thin bedded, much iron stained, sometimes with beds so ferruginous as to be almost a reddish brown sandstone, and without pebbles.

This sandstone rests directly upon the micaceous slate holding kidney iron ore balls, which overlies the Kidney coal bed

Morris Run Mines.

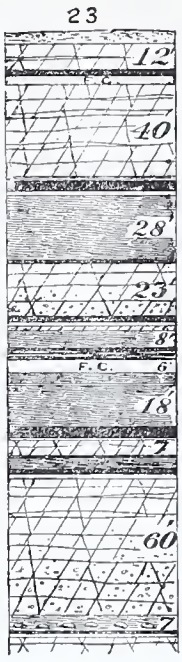
Only two miles west of Fall Brook are the extensive mines of the Morris Run Coal Company. These mines are opened and worked by the company, on Morris run, three miles east from Blossburg.

They have their own railroad to Blossburg, and a most extensive and complete plant at their mines.

The mines are 1,678 feet above tide water, and are geologically just about at the centre of the basin, or on the middle of the synclinal axis.

The detailed section of the measures showing at Morris run is thus given by Mr. W. S. Neering, Superintendent. The numerous test pits, air shafts, &c., have enabled these measures to be given in complete detail.

The section is:



Surface,	
Drift,	5′ 0″
Firegrit sandstone,	12′ 0″
Coal, ("Rock Vein,")	2′ 6″
Fireclay,	4′ 0″
Yellow sandstone,	40′ 0″
Slate,	2′ 0″
Coal, ("Seymour, or Cushing Vein,")	4′ 6″
Fireclay,	2′ 0″
Slate,	28′ 0″
Coal,	1′ 6″
Sandstone and conglomerate,	23′ 0″
Coal, ("Dirty Vein,")	2′ 6″
Fireclay,	2′ 0″
Sandstone,	2′ 0″
Slate,	8′ 0″
Cannel coal and slate,	5′ 0″
Fireclay,	0′ 0″
Slate,	5′ 0″
Fireclay,	1′ 3″
Slate,	18′ 0″
Coal, ("Bloss Vein,")	5′ 0″
Fireclay,	1′ 0″
Sandstone,	7′ 0″
Coal,	1′ 0″
Slate,	5′ 0″
Coal, ("Bear Creek,")	2′ 6″
Fireclay,	2′ 0″
Sandstone and conglomerate,	60′ 0″
Slate (and iron ore,)	7′ 0″
Coal, ("Kidney Vein,")	1′ 0″
Fireclay,	1′ 0″
Sandstone,	
	266′ 6″

The upper bed of coal at Morris Run, the "*Rock Vein*," 46 feet above the "Seymour or Cushing Vein," is not worked for shipment. From openings made on the outcrop it is called a 2½ foot bed.

The *Seymour bed* has also only been opened up on the crop, and is not shipped to market.

As it underlies a considerable area in this region, and is usually of workable thickness, it was deemed advisable to ascertain its character. A specimen of the coal was taken from under good cover and forwarded to the laboratory at Harrisburg. It yielded on analysis (McCreath):

The coal has a deep black lustre, is very tender, and contains an unusually large number of thin partings of iron pyrites. These are generally nothing more than mere knife edges, but the number present in the specimen examined is very unusual.

Water,	.950
Volatile matter,	19.830
Fixed carbon,	60.759
Sulphur,	6.856
Ash,	11.605
	100.000
Coke, per cent.,	79.22

Sulphur left in coke,	4.375
Per cent. sulphur in coke,	5.522
Per cent. iron in coal,	5.558
Sulphur taken up by iron,	6.352
Free sulphur,	.504
Per cent. sulphur volatilized by coking,	36.180

The above analysis is a striking example of how easily the use of a single specimen for analysis may lead into grave error.

The analyses of the Seymour Vein coal from Fall Brook, Arnot and Antrim, all show that the Seymour coal carries much more sulphur than the Bloss coal, but is regular in its character, not exceeding say 2 per cent. of sulphur. There is no reason to believe that the average character of the bed at Morris Run is materially different, but it appeared that the lump selected for analysis contained numerous small scales of iron pyrites, not visible save by close examination under a strong glass.

It is, therefore, a totally unfair representation of the character of the Seymour coal bed in the region between Fall Brook and Arnot, and is only reproduced here to show that the analyses, though perfectly accurate for the specimens forwarded, must be closely scanned in connection with all the other features of the case before they can be accepted as conclusive of character.

Moreover, the analysis is of importance as bearing on the question of how far the *condition* of the sulphur in the coal affects the *percentage driven off* in coking. This subject will be discussed in another place.

The coal beds between the Seymour coal and the Bloss coal have not been opened up at Morris Run, except in passing through them in air shafts, &c. They are small, and of no present practical value.

The vertical sections of Fall Brook and Morris Run show that while in the main broad features there is harmony between them, yet that even in the short interval between the two places, only 2 miles, there has been sufficient room for minor details of difference to grow into marked features, which if not accompanied by the complete section, with its

general resemblance, would cause embarrassment of identification.

The *Bloss coal bed* is the one from which the widely known and esteemed Morris Run coal has been mined and shipped.

The bed is here at its very best. In size it has now full 5 feet or more of clean coal for long distances in the mines, with excellent roof and floor, lying so well for easy mining that a single mine upon it has yielded 1,500 tons of coal daily for a considerable period, when the demand for coal pushed the mining.

In character, appearance, bearing of transportation, &c., this coal is not excelled by anything in the Blossburg coal basin.

A specimen of the coal of the Bloss bed at Morris Run, representing the average run of mine of the coal as shipped to market, was forwarded to the laboratory of the survey, and yielded on analysis (McCreath):

The coal is generally bright, tender, columnar, and shows a few thin seams of cannel-like coal. It carries some mineral charcoal, and a very small amount of iron pyrites, in thin partings.

Water,	1.120
Volatile matter,	18.570
Fixed carbon,	72.097
Sulphur,	.583
Ash,	7.630
	100.000
Coke, per cent..	80.33
Color of ash,	gray.
Sulphur left in coke,	.497
Per cent. sulphur in coke,	.618
Per cent. iron in coal,	.133
Sulphur taken up by iron,	.152
Free sulphur,	.431
Per cent. sulphur volatilized by coking,	14.750

It is scarcely necessary to call attention to the analysis given above. It shows that the Morris Run coal possesses all the attributes of a steam coal, and is very free from injurious impurities.

And this character is borne out by the reputation already earned by the coal after a shipment to market of over three millions of tons.

Neither the Bear Creek coal, nor the Kidney coal are developed at Morris Run.

From outcrop openings merely the *Bear Creek* is reported as showing 2½ feet of coal, and the *Kidney* coal as giving 1 foot of coal. Neither one is now open for examination.

The lower part of the section is almost identical with the measures as shown on the Fall Brook section, and the description given of them at that place will also apply in its general features to the measures under the Bloss bed at Morris Run.

Blossburg.

No coal mining for shipment to market is now done in the immediate vicinity of the town of Blossburg. The Bloss bed covered only a limited area on the hill top near the town, and this area was steadily worked for many years. The section reproduced on page 163 from the Roger's Final Report of 1858 was made when the works at Blossburg were running, and is much more complete than could now be obtained.

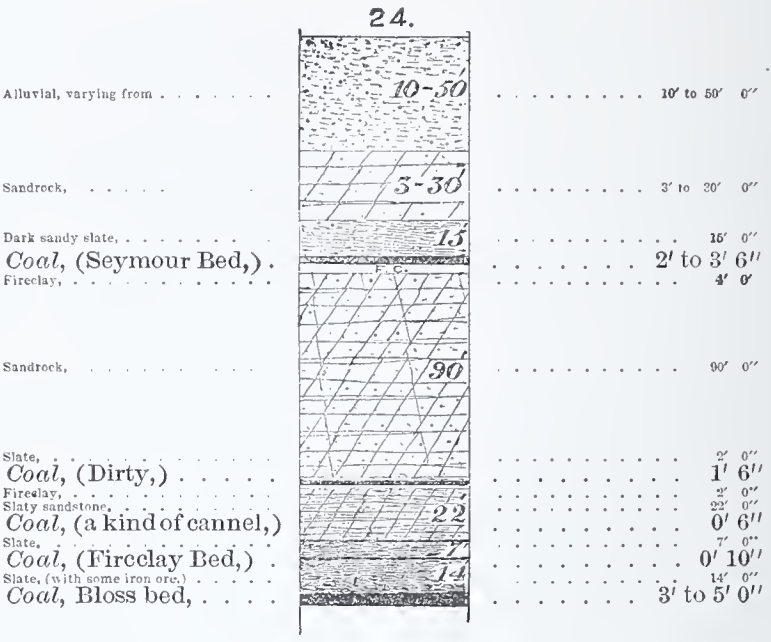
In view of the reproduction of this complete section, and the fact that complete details are given in this report of the mines lying both east and west of Blossburg, the immediate vicinity of the town, therefore, will need no further elaboration of detail in this chapter.

Arnot Mines.

The Blossburg Coal Company have their mines opened at Arnot, 3 miles west of Blossburg. The company have their railroad to Blossburg (and on to Elmira), a well built village at Arnot, coal shutes, coke ovens, and everything necessary for a complete and efficient plant to mine and ship economically and quickly a large daily output of coal. Arnot is 1682 feet above tide water. The measures exposed resemble in their main features the sections at Fall Brook, Morris Run and Blossburg.

The details of the vertical section as given by Mr. S. B. Elliott, the general manager of the company, are as follows:

Section at Arnot.


24.
Alluvial, varying from . . . . . 10′ to 50′ 0″
Sandrock, ... 3′ to 30′ 0″
Dark sandy slate, ... 15′ 0″
Coal, (Seymour Bed,) . . . . . 2′ to 3′ 6″
Fireclay, ... 4′ 0″
Sandrock, ... 90′ 0″
Slate, ... 2′ 0″
Coal, (Dirty,) . . . . . 1′ 6″
Fireclay, ... 2′ 0″
Slaty sandstone, ... 22′ 0″
Coal, (a kind of cannel,) . . . . . 0′ 6″
Slate, ... 7′ 0″
Coal, (Fireclay Bed,) . . . . . 0′ 10″
Slate, (with some iron ore,) . . . . . 14′ 0″
Coal, Bloss bed, ... 3′ to 5′ 0″
10-50
3-30
15
F. C.
90
1
22
7
14

A diamond drill boring starting between the Bloss and Bear Creek coals continues the section on downwards, thus:

Sandstone,	11′ 0″
Coal, Bear Creek,	0′ 3″
Sandstone,	13′ 0″
Sandstone,	15′ 0″
Slate,	5′ 0″
Coal,	0′ 3″
Sandstone,	12′ 0″
Sandstone and slate,	5′ 0″
Coal, Kidney,	0′ 6″
Sandstone and slate,	10′ 0″
Small *coal*, ½ inch,	——
Sandstone and slate,	5′ 0″
Small *coal*, ½ inch,	——
Sandstone, some slate layers,	80′ 0″
Sandstone, massive,	5′ 0″
Slates,	3′ 0″
Coal,	0′ 2″
Fireclay, some sandstone layers,	10′ 0″
Conglomerate sandstone,	9′ 0″
Sandstone,	12′ 0″
Sandstone,	3′ 0″
Red rock,	15′ 0″
Total,	214′ 2″

The above measurement is taken from the core. It is incorrect, the core being imperfect, and much of the soft rock ground up.

The red rock, by measurements made at other points, is said to be fully 300 feet below the Bloss bed of coal; and in this case there is an error of 60 feet to be distributed through the above section, representing soft rocks of which no core came out.

This bottom red rock is about 6 feet thick; under it comes in a massive fine grained gray sandstone.

The *Seymour* coal bed is opened and worked for shipment by the Blossburg Coal Company at Arnot.

The bed has a slate roof with $\frac{1}{2}''$ to $3''$ of iron ore enclosed, and a fireclay floor; runs with considerable regularity in the mine, and will average two feet eight inches in thickness.

An average specimen of the coal was forwarded to the Survey laboratory, and yielded on analysis (McCreath):

The coal is bright, shining, and very tender. It carries numerous thin partings of iron pyrites, and an unusually large amount of mineral charcoal.

Water,	1.180
Volatile matter,	21.586
Fixed carbon,	71.574
Sulphur,	.907
Ash,	4.753
	100.000
Coke, per cent.,	77.234
Color of ash,	Reddish gray.

A coke made from this coal yielded on analysis (McCreath):

Water,	.220
Volatile matter,	.625
Fixed carbon,	90.650
Sulphur,	.850
Ash,	7.655
	100.000
Color of ash,	Gray, with red tinge.

Both the above coal and coke are of excellent character; perhaps rather higher in character than would be yielded as an average by working extensively.

The coal beds between the Seymour and Bloss coal beds are not opened up at Arnot for shipment; and where they have been touched in test pits, or in air shafts, they have proved themselves small and valueless, as is shown on the vertical section of the Arnot measures.

The "*Monkey Ridge*" shows as clearly at Arnot as at Fall Brook, and is at the former as a much current bedded sandstone, with layers of pebble rock interleaved, usually forming a cliff on the hill side, and always a marked feature and a guide for geological position.

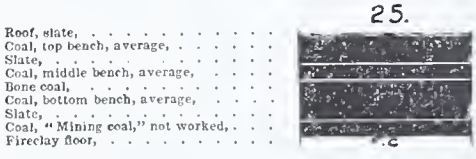
The *Bloss coal bed* is the bed which furnishes the greater part of all the coal which has been in the past, and is now being shipped from Arnot.

It is of its usual excellent character, and is very regular in average thickness.

There are, of course, numerous local pinches and swellings in size, as there are in all mines; but on the average it yields about three feet six inches of clear coal, or over 5,000 tons to the acre.

The coal is divided into benches; the partings being very persistent, and recognizable under their change in thickness.

On the average, the bed shows thus:



The mining coal on the bottom of the bed is all cut up in mining, and is not counted in the estimate of the producing power of the bed.

The coal separates cleanly from the parting slates usually, except that the coal from the middle bench shows a tendency to stick to the top of the bone coal under it. This however is picked clean outside of the mine.

Specimens of the coal from the three workable benches were forwarded to the laboratory of the survey for analysis.

The upper bench yielded (McCreath):

Water,	1.190
Volatile matter,	20.755
Fixed carbon,	71.697
Sulphur,	1.023
Ash,	5.335
	100.000
Coke, per cent.,	78.055
Color of ash,	gray.

This upper bench averages 12 inches of clean coal. Though a little high in sulphur, it is very low in ash, and is the purest and strongest bench of coal in the whole bed.

The middle bed yielded on analysis (McCreath):

Water,	.940
Volatile matter,	20.640
Fixed carbon,	64.306
Sulphur,	.914
Ash,	13.200
	100.000
Coke, per cent.,	78.420
Color of ash,	gray.

This bench averages only about 8 inches in thickness. It is a good coal, though higher in ash than the upper bench.

The lowest workable bench of the coal yielded on analysis (McCreath):

Water,	1.110
Volatile matter,	18.790
Fixed carbon,	63.428
Sulphur,	.602
Ash,	16.070
	100.000
Coke per cent.,	80.100
Color of ash,	gray.

This is the main bench of coal, which yields nearly one half of all the coal coming from the Bloss bed. The percentage of ash as given by the analysis is probably higher than the average of the bed.

It is plain that a combination of the coal of these three benches, as shipped to market, will make a coal not specially high in sulphur, representing a strong steam coal somewhat high in ash.

While the Bloss bed averages from 3 to $3\frac{1}{2}$ feet of coal, say fully $3\frac{1}{4}$ feet, or 5,000 tons to the acre, some of the variations in the mine are very great.

The top bench is probably the most regular, keeping steadily at about 1 foot thick. It carries a "sulphur band," which can be picked out.

The slate partings run from 2 inches to 18 inches. All of them vary much, the bottom slate at times running down to less than $\frac{1}{4}$ of an inch.

While the chief business of the Blossburg Company at Arnot has been and is now the shipment of coal for steam and blacksmiths' use, yet well directed efforts are now being made to utilize the slack from screening by coking to ship to foundries and furnaces.

Coking.

In view of the importance to the region of the developement of this branch of trade, analyses were made of three different cokes, and one of them was tested also for burden bearing power.

The coke is made in beehive block ovens; is burned for 48 hours; is watered in the oven, as in the Connellsville region, and shows where properly burned as an open, porous, cellular, ringing, and strongly coherent coke.

It should be stated again that in mining on the Bloss bed, the middle bench coal sticks to the bone coal beneath so closely "that it is necessary to allow the miner to send the latter out, and it is taken out and cleaned at the chutes. This is done on screens over which the coal passes, and more or less of this bone is broken up in the operation, and falls in among the fine coal; and it is from the fine coal that we are now making our coke. This will explain why the coke from our No. 2 Drift, or Bloss Vein, shows so much impurity in the form of small pieces of slate and bone. This we propose to take out with a machine similar to the one used at Loyalhanna, in Westmoreland county."

The coke from the No. 2, north drift, Bloss Vein, yielded on analysis (D. McCreath):

Water,	.590
Volatile matter,	.845
Fixed carbon,	83.371
Sulphur,	.644
Ash,	14.550
	100.000
Color of ash,	Gray.

Another coke made from Bloss Vein coal, yielded (D. McCreath):

Water,	.240
Volatile matter,	.572
Fixed carbon,	83.922
Sulphur,	.679
Ash,	14.587
	100.000
Color of ash,	Gray.

These analyses showed a coke of good enough character, and apparently of sufficient strength to enable them to be applied to any of the ordinary uses for which coke is desired.

Some coke was then made from the fine coal screenings, and then tested for strength and burden bearing power.

The coal used was from the fine coal screened from market sales (Bloss bed coal).

Its general character is represented by an average of the analyses of the Bloss coal already given.

It was coked for 48 hours in the Beehive Oven; watered in oven.

The coke showed on analysis (McCreath):

The coke is generally fine, although somewhat open and porous in centre of lump. It has a bright steel-gray color, and carries considerable slate in small lenticular masses.

Water,	1.150
Volatile matter,	1.732
Fixed carbon,	80.927
Sulphur,	.764
Ash,	15.427
	100.000
Color of ash,	Reddish gray.

Both in character, general appearance and strength the coke shows very well, more especially as the enterprise when examined was comparatively new.

Specimens of the coke were forwarded to Jno. Fulton, General Mining Engineer of the Cambria Iron Company, at Johnstown, Pennsylvania, who kindly consented to test the burden-bearing power.

Mr. Fulton reports as follows:

"The coke is bright, resonant, and possesses a superior physical structure. It requires washing of the fine coal to remove considerable slate scales and increase its tenacity. With this cleansing it would make a very excellent coke for blast furnace use, carrying a burden of furnace 60 to 80 feet high."

The following table, prepared by Mr. Fulton, shows at a glance the physical properties of the coke, as compared with Connellsville coke as a standard:

Table exhibiting the physical properties of coke, submitted by F. Platt, Esq., Assistant Second Geological Survey of Pennsylvania.

Locality.	Grammes in 1 cubic inch.		Pounds in 1 cubic foot.		Percentage.		Compressive strength per cubic feet in lbs.—¼ ultimate strength.	Height of furnace charge, which can be supported without crushing.	Order in cellular space.	Remarks.
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.				
Pittsburgh and Connellsville Coke Company, taken as a standard for comparison, .	12.46	20.25	47.47	77.15	61.53	38.47	284	114	I.	Very good furnace coke, . .
Arnot No. 1, ...	13.09	20.87	49.59	77.17	67.51	32.49	150	63	I.	With coal washed, a very excellent coke can be made.
Arnot No. 2, ...	11.16	18.67	42.50	71.12	59.71	40.29	142	57	I.	

The Blossburg Coal Company have not opened or worked the Bear Creek coal.

The vertical section given on page 178 shows that both the *Bear Creek* and *Kidney coal* are small and entirely valueless.

The boring made by the company at Arnot, 300 feet deep, carrying the section down into XI and X, has been given in detail on page 178.

It shows under the Bear Creek coal the same massive gray sandstone with but little pebble rock, much the same as has been recorded in detail concerning the measures at Fall Brook.

Antrim Mines.

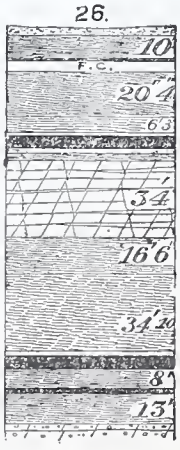
The Fall Brook Coal Company, in addition to their large plant at Fall Brook, have extensive works at Antrim, eight miles west from Arnot.

The deep cutting Babb's creek is between Antrim and Arnot, and necessitates an entirely separate outlet for the Antrim coals.

This is afforded by the Corning, Cowanesque and Antrim railroad, (which is in practically the same ownership,) by which the coal is transported via Corning, N. Y., on to Geneva, N. Y., on the New York Central railroad.

The mines at Antrim are 1,672 feet above tide.

The vertical section of the measures exposed at Antrim, are thus given in detail by Mr. Hardt, the chief engineer of the company:



Surface,		—
Drift,	5′	0″
Blue slate,	10′	0″
Coal,	1′	0″
Bluish fireclay,	5′	0″
Brown slate,	20′	4″
Blue slate,	6′	3″
Black slate,	1′	4″
Coal, ("Cushing, or Seymour,")	5′	6″
Fireclay,	2′	6″
Light slate,	3′	0″
Sandstone,	34′	0″
Light rock slate,	16′	6″
Dark slate,	34′	0″
Light slate,	2′	0″
Coal, ("Bloss Vein,")	5′	4″
Black slate,	8′	0″
Coal, Bear Creek,	2′	2′
Light-colored slate,	13′	0″
Conglomerate sandstone,		—
Total,	175′	9″

The points of difference between this vertical section and those at Arnot, Morris Run, and Fall Brook, are very striking. Some coal beds are absolutely lacking; the interval rocks are different in character, and the interval distances are amazingly changed. The discussion of these changes will be found in another chapter.

The small 1 foot coal, overlying the Seymour or Cushing bed at Antrim by 33 feet, has not been opened and was not examined.

The *Seymour bed* at Antrim is given by Mr. Hardt as 5 feet 6 inches in thickness. It is not at present mined to any extent, the Antrim coal coming from the Bloss bed.

A specimen of the Seymour coal from Antrim was forwarded to the State laboratory, and yielded on analysis (McCreath):

The coal has a bright, black lustre, is very tender, and carries numerous thin partings of mineral charcoal and knife edges of iron pyrites.

Water,	1.460
Volatile matter,	21.600
Fixed Carbon,	65.120
Sulphur,	2.820
Ash,	9.000
	100.000
Coke, per cent.,	76.940
Color of ash,	Reddish gray.

The percentage of sulphur in the above coal is damagingly high. If, however, it runs on the average lower than as given above, the coal would prove a strong and efficient steam coal.

The *Bloss bed* at Antrim, however, is depended upon for the coal shipped to market. (There is at Antrim *no coal* between the Seymour and the Bloss bed according to Mr. Hardt's section.)

It is given in the section as 5 feet 4 inches thick. It does not, of course, hold this thickness all through the workings, but in many cases runs down very considerably, as might reasonably be expected. It has proved, however, to be a reliable and profitable bed, as persistent in char-

acter and size as the same bed at other places in the basin.*

A specimen of the fair average of the run of the mine of the Bloss bed at Antrim, representing all the benches together, just as the coal goes to market, was forwarded for analysis, and yielded (McCreath):

The coal has a deep black lustre generally, with seams of bright crystalline coal running through it. It is rather tender, is free from slaty coal, and carries only a small amount of iron pyrites.

Water,	2.260
Volatile matter,	20.240
Fixed carbon,	71.847
Sulphur,	.548
Ash,	5.105
	100.000
Coke, per cent.,	77.50
Color of ash,	Gray.

The above analysis represents a coal of most superior character; low in ash, low in sulphur, and with every requisite for a most efficient and valuable fuel.

The percentage of combined water runs curiously higher than the average of specimens of Bloss coal mined in this basin.

West of Wilson's Creek

West of Antrim is Wilson's Creek, a large stream which cuts down 600 to 700 feet below the hill tops which hold the coals.

Coal has been opened up and is now worked on the West side of Wilson's Creek, opposite to Antrim; and the Bloss bed on the west side appears to be fully 30 to 40 feet higher than the level of the same bed at Antrim.

* A rounded white quartz pebble, 3½ inches by 2½ inches in size, smooth and waterworn, was found in the Antrim Mine on the Bloss bed, by John Prethero, miner, May, 1878. The specimen was given to Mr. James MacFarlane, of Towanda, who has presented it to the Survey Collection at Harrisburg.

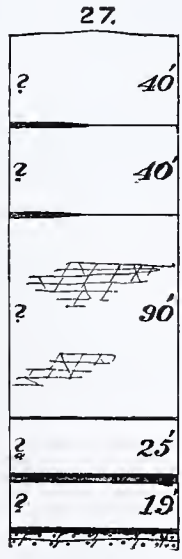
The curious feature is that this large stone was found in solid coal, near the top of the bed. No slate nor wash was near it, but the specimen itself shows that it was in coal, the irregularities on its surface being now filled with pure coal.

In view of the nature of the vegetable growth from which coal was formed, the presence of this large pebble entirely alone, close packed into pure coal, is very noteworthy.

There is no railroad communication at present to afford an outlet to market for any coal west of Wilson's Creek: but some few mines are opened, and one or two thousand tons of coal are mined yearly and hauled away, mainly on sleds in winter, for use in Wellsboro' and the adjacent country.

The region is entirely undeveloped, except these few openings; and it is, therefore, impossible from surface examination, to obtain more than a very incomplete section of the measures as they exist on the west side of Wilson's Creek.

The vertical section as obtained near Bache's mines, 10 miles south of Wellsboro', Tioga county, is as follows:



Hill top,	—
Concealed,	40′ 0″
Bench *coal*, rep'ted once opened.	
Concealed,	40′ 0″
Coal, once opened, reported as having yielded 2 feet of good coal.	
Concealed, (clearly much sandstone,)	90′
Coal,	0′ 8″
Concealed,	25′ 0″
Coal, (Bloss bed, Bache Mine,)	3′ 4″
Concealed,	—
Bear Creek *coal*, reported 19 feet below the Bloss bed, and showing 2 feet thick, (at Mitchell's, one mile away,)	21′ 0″
Massive congl'm'ate SS.,	—
Total,	220′ 0″

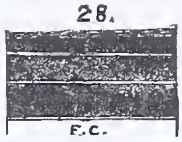
The above imperfect section was the best which could be made without special development for the purpose; but it is sufficient to show that the measures of Arnot and Antrim cross Wilson's Creek and continue to the West of it. The Blossburg Coal basin, therefore, runs from Fall Brook on the East to where the basin points out some 1 or 2 miles ± west of Bache's mine.

None of the coal beds of the above section are opened up for examination, except the *Bloss bed.*

At the *Bache mine* the coal is worked for local supply.

The mine runs in South 50° West, and the workings are carried to the South, the coal rising in that direction.

The coal measures in the mine as follows:



Roof, black slate,	
Coal,	8″ to 0′ 10″
Slate parting, persistent,	1″ to 0′ 1½″
Coal,	1′ 0″
Slate parting, persistent,	0′ 1½″
Coal,	1′ 5″
Bone coal and slate,	0′ 2 ″
Fireclay floor,	

In working this coal, some of it is hard, breaking up into blocks, while the balance of the coal is only moderately compact.

These coals were analyzed separately.

The hard coal from the Bache mine yielded on analysis (McCreath):

The coal is considerably coated with an orange yellow silt, is unusually firm and compact, and has a deep black lustre on clean fracture. It shows numerous thin partings of mineral charcoal, and has a decided tendency to break up into blocks.

Water,	2.380
Volatile matter,	20.005
Fixed carbon,	70.055
Sulphur,	.565
Ash,	6.995
	100.000
Coke, per cent.,	77.615
Color of ash,	Reddish gray.

The softer coal from the Bache mine yielded on analysis (McCreath):

The coal, clean looking generally, has a deep black lustre. It is moderately firm and compact, and shows numerous thin partings of mineral charcoal. It breaks with irregular fracture.

Water,	2.240
Volatile matter,	20.045
Fixed carbon,	70.357
Sulphur,	.588
Ash,	6.770
	100.000
Coke, per cent.,	77.715
Color of ash,	Gray, with red tinge.

These coals from the Bache mine, therefore, though so

unlike in appearance and physical structure, are almost perfectly identical in chemical composition.

If the analyses of the specimens forwarded from the mine will represent what would be afforded as an average of extensive workings, the coal of the Bloss bed west of Wilson's Creek is fully equal to any coal from the same bed now worked in the Blossburg Coal Basin.

About one mile North-east from the Bache mine, the *Bloss bed* is opened and worked at *Mitchell's mine*, on the west bank of Wilson's Creek, opposite to the Antrim mines.

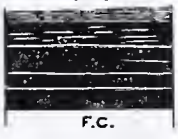
The mine is worked on a small scale, only to supply one or two thousand tons for local use. It has no railroad communication, and its yield is hauled away on wagons and sleds.

The Bloss bed here makes a beautifully defined bench around the hill sides.

The mine runs in North 10° West, and where measured the coal shows thus:

The drift has been run in far enough to secure clean, bright, hard coal, with good roof and floor: and some fair average specimens were taken from the run of mine coal, as it is now shipped from the mine, and forwarded to the Laboratory of the survey at Harrisburg. They yielded on analysis (McCreath):

Roof, black slate,		
Coal, somewhat bony in places,		0′ 10″
Slate parting,		2″ to 0′ 3″
Coal,		1′ 0″
Slate parting,		2″ to 0′ 3″
Coal,		0′ 6″
Slate,		½″ to 0′ 1″
Coal,		0′ 11″
Fireclay floor,		



The coal is bright and compact, with much mineral charcoal.

The coal, considerably coated with silt, has a dull dead lustre on fresh fracture. It is generally compact, carries numerous thin partings of mineral charcoal, and seems in the main free from iron pyrites.

Water,	1.810
Volatile matter,	20.350
Fixed carbon,	68.126
Sulphur,	.569
Ash,	9.145
	100.000
Coke, per cent.,	77.84
Color of ash,	Reddish gray.

The analysis shows that the Mitchell and Bache coals are almost identical in composition. The former carries a little more ash in this analysis, but such slight variation is due most probably to the specimen selected, and not to any permanent change in the character of the coal at the Mitchell mine.

It fully equals the average character of the coal mined from the Bloss bed, throughout the Blossburg coal basin, and is of, at least, the average thickness also.

The coal at these mines is screened for use, the lump coal only being used, and most of the fine coal thrown away. No attempt has ever been made to coke this slack.

The *Bear Creek coal* is reported to have been shafted down to at the Mitchell mine and to have been found 19 feet below the Bloss bed 2 feet thick and of good character.

It is not now open and could not be examined at the time (November, 1877).

Various other test openings have been made in the region lying south-west, and south of the Bache mine. In the absence of a complete detailed survey of the region and with incomplete openings, it would be difficult to identify which coal bed had been touched in each case, nor is it needful to do so.

Clearly the Lower Productive Coal Measures, not in whole thickness, but in part, occupy a narrow basin west of Wilson's creek for an area of apparently of about 1 mile across from north to south and about $1\frac{3}{4}$ miles from east to west.

The conglomerate rock under the Bear Creek coal sweeps

around the basin in a well defined line, making in many places along the south line a clearly marked cliff wall, and also plainly showing on the north line.

Within these limits of the conglomerate the Lower Productive Coals are present, but in some parts only the lowest coal beds are included.

When the Bloss bed comes to daylight on the north outcrop of the basin, it is as a bed of fully as great size as at Bache's mine, or greater; but the coal is more friable and columnar, and breaks up so much in mining as to afford but little lump coal, most of it coming out as fine coal.

The opening on the north crop is fully one hundred feet higher than the south outcrop of the Bloss bed. The south crop has only been touched in a trial pit, and no accurate measurement of the bed could be made.

The conglomerate of XII shows along the south rim of the basin as a massive gray sandstone, filled with pebbles of rounded quartz, mostly pea sized. It seemed to be dipping quite decidedly to the N. 20° W ±; probably the rocks had slipped slightly and had exaggerated the dip, which should not be so great.

The north dip on the south side of the basin, however, is apparently much steeper than the south dip on the north side of the basin.

These coal openings are 10 miles from Wellsboro, which is their nearest railroad connection.

The basin appears to point out sharply to the west, and no coal is opened in the hills to the westward of the district described above.

Chapter XIII.

Character and Uses of the Blossburg Coal.

The analyses of the coals and cokes of the Blossburg Coal Basin have been given in connection with the detailed report upon the different places now working coal in the region.

For convenience of reference in comparing character, the analyses are grouped below under the headings of the different coal beds. It should be stated that taking large quantities for an average, all the coal from the Bloss bed shipped may be said to be closely alike, no matter from which mines it may have been extracted; extra care in mining, picking slate, &c., of course making some difference in forming a reputation among consumers of the fuel.

Any great variation in a single analysis, therefore, may be taken as due to an imperfect specimen; the enormous percentage of sulphur in one analysis of Seymour coal being clearly due to iron pyrites which was hidden in the block, and never discovered until the coal was ground up in the laboratory. The tables of analyses must be considered for general averages, any single analysis having but slight weight, and indeed such analysis must be entirely cast out from the scale whenever it comes in contact with a well established general average, founded upon numerous analyses agreeing well with each other.

Table of Analyses of Blossburg Coals.

"Seymour Coal Bed."

No. 1. Fall Brook.
No. 2. Morris Run.
No. 3. Arnot.
No. 4. Antrim.

	1.	2.	3.	4.
Water,	1.970	.950	1.180	1.460
Volatile matter,	20.105	19.830	21.586	20.600
Fixed carbon,	68.360	60.759	71.574	65.120
Sulphur,	1.795	6.856	.907	2.820
Ash,	7.770	11.605	4.753	9.000
	100.00	100.00	100.00	100.00
Coke per cent.,	77.925	79.22	77.234	76.940
Color of ash,	Lilac.	Deep pink.	Reddish gray.	Reddish gray.

"Monkey Coal Bed."

From Fall Brook opening:

Water,	1.560
Volatile matter,	20.740
Fixed carbon,	66.587
Sulphur,	.773
Ash,	10.340
	100.000
Coke per cent.,	77.700
Color of ash,	Reddish gray.

"Dirty Coal Bed."

From Fall Brook opening:

Water,	2.820
Volatile matter,	17.975
Fixed carbon,	71.326
Sulphur,	.634
Ash,	7.245
	100.000
Coke per cent.,	79.205
Color of ash,	Reddish gray.

"Bloss Coal Bed."

No. 1. Fall Brook.
No. 2. Morris Run.
No. 3. Arnot. Upper bench.
No. 4. Arnot. Middle bench.
No. 5. Arnot. Lower (or main) bench.
No. 6. Antrim.
No. 7. Bache Mine—West of Wilson's Creek.
No. 8. Mitchell Mine—West of Wilson's Creek.

	1.	2.	3.	4.	5.	6.	7.	8.
Water, ...	1.050	1.120	1.190	.940	1.110	2.260	2.240	1.810
Volatile matter,	18.540	18.570	20.755	20.640	18.790	20.240	20.045	20.350
Fixed carbon, .	69.934	72.097	71.697	64.306	63.428	71.847	70.357	68.126
Sulphur, ...	.661	.583	1.023	.914	.602	.548	.588	.569
Ash, ...	9.815	7.630	5.335	13.200	16.070	5.105	6.770	9.145
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Coke per cent.,	80.41	80.33	78.055	78.420	80.100	77.50	77.715	77.84
Color of ash, . .	Gray.	Gray.	Gray.	Gray.	Gray.	Gray.	Gray red tinge.	Reddish gray.

"Bear Creek Coal Bed."

From Fall Brook opening:

Water,	.790
Volatile matter,	20.965
Fixed carbon,	65.465
Sulphur,	.725
Ash,	12.055
	100.000
Coke, per cent.,	78.225
Color of ash,	gray.

Cokes from Blossburg Coals.

No. 1. Arnot. Bloss Vein coal. North Drift.
No. 2. Arnot. Bloss Vein coal.
No. 3. Arnot. Bloss Vein, fine coal from screening.
No. 4. Arnot. Seymour Vein coal.

	1.	2.	3.	4.
Water, ...	.590	.240	1.150	.220
Vol. matter, . .	.845	.572	1.732	.625
Fixed carbon, .	83.371	83.922	80.927	90.650
Sulphur, ...	.644	.679	.764	.850
Ash, ...	14.550	14.587	15.427	7.655
	100.000	100.000	100.000	100.000
Color of ash, . .	Gray.	Gray.	Reddish gray.	Gray with reddish tinge.

Numerous analyses of the Blossburg Coals have been made at different times for the Fall Brook Coal Company. These analyses are furnished for publication by Mr. A. Hardt, Chief Engineer of the Company, and are reproduced

below for the purpose of showing more completely the general average character of the "Bloss Coal."

Analysis of Fall Brook Coals in 1859 by Prof. Silliman:

No. 1 Drift. Bloss Vein.

Moisture expelled at 212°,	0.99
Volatile matter at redness,	17.23
Carbon,	76.01
Ash,	5.78
	100.00
Coke,	87 per cent.

No. 3 Drift, (Bloss Vein,) 3 samples.

	a.	b.	c.
Moisture,	0.96	1.08	1.12
Volat. matter,	18.04	17.36	18.92
Carbon,	76.55	72.86	74.61
Ash,	4.45	8 70	5.35
	100.00	100.00	100.00
Coke,	84 per cent.	82 per cent.	80 per cent.

No. 1 a Drift, (Seymour Vein,) 3 samples.

	a.	b.	c.
Moisture,	0.91	0.92	0.91
Gas,	17.77	15.62	16.65
Carbon,	72.92	65.86	73.49
Ash,	8.40	17.60	8.95
	100.00	100.00	100.00
Coke,	81 per cent.	83 per cent.	82 per cent.

Analyses, made Aug. 1874, by Hugh Hamilton, Harrisburg, Penn'a.

	Bloss. V., Antrim. Drift No. 1.	Bloss. V., Antrim, Drift No. 2.	Seymour V., Antrim.	Bear Creek V., Fall Brook.	Bloss. Vein, Fall Brook. No. 3 Drift.	Bloss. Vein, Fall Brook. No. 2 Drift.
Moisture,	0.65	0.72	0.80	0.47	0.45	0.47
Volatile matters,	21.65	20.68	24.47	21.35	19.40	17.78
Fixed Carbon,	73.40	74.63	70.63	68.45	69.67	68.42
Ash,	4.30	3.97	4.10	9.73	10.48	13.33
Sulphur,	0.29	0.50	0.39	0.20	0.31	0.35
Coke,	77.70	78.60	74.73	78.18	80.15	81.75

Analyses by J. B. Britton, March, 1877.

	Moisture.	Volatile matter.	Ash.	Fixed carbon.	Sulphur.	Coke.	Sulphur in 100 parts of the coke.
Antrim No. 1, (Bloss V.,)	1.63	18.38	4.73	75.26	0.511	79.99	0.397
Antrim No. 2, (Bloss V.,)	1.46	18.73	6.21	73.60	0.522	79.81	0.549
Antrim Seymour Vein,	1.27	21.10	6.84	70.79	2.209	77.63	1.715
Fall Brook No. 2, (Bl. V.,)	1.07	21.64	11.47	65.82	0.754	77.29	0.550
Fall Brook No. 3, (Bl. V.,)	1.05	17.94	7.71	73.30	0.686	81.01	0.651

In discussing the character and uses of Blossburg Coal it must be understood that by that name, at present, is only meant the coal from the "Bloss bed," inasmuch as that bed alone supplies nearly all the coal which comes to market from the basin. The detailed report has shown the number, thickness, and character of the other coal beds, and thus enabled them to be compared to the Bloss bed coal; but the present discussion of Blossburg Coal is confined entirely to the coal from the great bed of the region—the Bloss bed.

In any examination of the character of a steam coal, the first reference is to the Report of Prof. Walter R. Johnson to the U. S. Navy Department, in 1844. No careful statistics upon the subject had preceded this Report, and so thoroughly and exhaustively was it made that now (35 years after the experiments) it stands as authority upon the subject.

Since that day there have been great changes in the practical relationship of the coals to the market. For example, the Clearfield Coal Region in Pennsylvania, which was then without connection with market, and could not even be tested, now ships (1877) annually about one and a quarter million of tons of coal, or nearly as much as the Cumberland Region in Maryland. The Richmond, Virginia, coals, which were then considered as of much importance have, for various reasons, dropped so steadily behind, that they may be now omitted from any list of steam coals, which deals only with the chief producing regions.

Prof. Johnson's tables show broadly the relationship between the character of a coal as shown by its analysis, with its total evaporative power, its rapidity of action, its efficiency within specified times, &c., &c.

In MacFarlane's Coal Regions of America these results have been conveniently grouped and the table below is reproduced from that work.

Results of United States Government Experiments in Burning Coal under a steam boiler.

ANTHRACITES.

	Analyses.				Efficiency.				
	Specific gravity.	Volatile combustible matter.	Fixed carbon.	Earthy matter.	Hours to bring boiler to steady action.	Cubic feet water evaporated per hour during steady action.	Pounds steam to one pound coal from initial temperature.	Pounds steam to one pound coal from 212°.	Steam from 212° from one pound combustible matter.
Beaver Meadow, ...	1.610	2.38	88.94	7.11	3.87	12.57	8.20	9.21	10.462
Beaver Meadow, ...	1.557	2.66	91.47	5.15	2.42	10.66	8.76	9.83	10.592
Forest Improvement, . .	1.477	3.07	90.75	4.41	3.32	12.89	8.92	10.06	10.807
Peach Mountain, ...	1.464	2.96	89.02	6.13	3.54	14.04	8.96	10.11	10.871
Lehigh, ...	1.590	5.28	89.15	5.56	3.27	11.63	7.73	8.93	9.626
Lackawanna, ...	1.421	3.91	87.74	6.35	2.67	11.92	8.56	9.79	10.764
Lykens Valley, ...	1.389	6.88	83.84	9.25	2.63	12.89	8.43	9.46	10.788
Beaver Meadow, ...	. . .	. .	. . . .	8.10	5.08	9.42	7.86	9.08	9.881
Average, ...	1.501	3.877	88.70	8.51	3.35	10.67	8.43	7.07	10.473
SEMI-BITUMINOUS.									
N. Y. and M. Mining Co.,	1.431	12.31	73.50	12.40	1.33	12.79	8.65	9.78	11.208
Neff's Cumberland, . . .	1.337	12.67	74.53	10.34	1.68	14.80	8.19	9.44	10.604
Easby's, Maryland, . . .	1.307	14.98	76.26	8.08	1.75	12.73	8.88	10.02	10.935
Atkinson & Templeton's,	1.313	15.53	76.69	7.33	0.99	15.70	9.47	10.70	11.624
Early's & Smith's, ...	1.332	15.52	74.29	9.30	1.52	14.97	8.67	9.96	11.034
Cumberland, Navy Yard,	1.414	14.87	70.85	14.98					
Dauphin & Susquehanna,	1.443	13.82	74.24	11.49	0.83	13.35	8.31	9.34	11.171
Blossburg, ...	1.324	14.78	73.11	10.77	0.84	15.67	8.64	9.72	10.956
Lycoming Creek, ...	1.388	13.84	71.53	13.96	1.72	12.13	7.92	8.91	10.724
Quin's Run, ...	1.331	17.97	72.79	8.41	0.75	13.90	9.08	10.27	11.275
Average, ...	1.362	14.62	73.78	10.70	1.26	14.00	8.83	9.68	11.059
BITUMINOUS.									
Karthaus, Penna., . . .	1.284	19.53	73.77	7.00	1.87	12.48	7.92	9.09	9.887
Cambria Co., Penna., . .	1.407	20.52	69.37	9.15	2.00	12.47	8.04	9.24	10.239
Picton, Nova Scotia, . .	1.318	27.83	56.98	13.39	0.94	12.79	7.48	8.41	9.710
Sidney, Nova Scotia, . .	1.338	23.81	67.57	5.49	1.18	13.85	7.01	7.99	8.497
Pictou, Cunard, ...	1.325	25.97	60.74	12.51	0.85	16.47	7.45	8.48	9.648
Liverpool, England, . .	1.262	39.96	54.90	4.62	0.86	13.43	6.95	7.48	8.255
Newcastle, England, . .	1.257	35.83	57.00	5.40	0.84	13.75	7.68	8.66	9.178
Scoteh, ...	1.519	39.19	48.81	9.34	0.96	14.32	6.14	6.95	7.719
Pittsburg, Penna., . . .	1.252	36.76	54.93	7.07	. . .	10.56	7.03	8.20	8.942
Cannelton, Indiana, . . .	1.273	33.99	58.44	4.97	0.50	15.05	6.31	7.34	7.734
Average, ...	1.3235	30.339	60.301	7.894	1.11	13.51	7.20	8.18	8.98

The above table gives the character and efficiency of the Anthracite coals, the Semi-bituminous coals, and the Bituminous coals in sufficient detail. The composition of the

Blossburg coals is given in the tables of analyses already compiled in this chapter.

The remaining great steam coal, the Clearfield coal, is shown by the complete table of analyses below. They are taken from the Report of 1874.*

By comparing these analyses and applying to them, according to their analyses, the efficiency of the coals in Johnson's table with which their analysis most closely corresponds, a close approximation to their efficiency as a steam raising fuel can easily be obtained.

Table of analyses of Steam Coals from Clearfield County, Penna.

No.	Water.	Volatile Matter.	Fixed Carbon.	Sulphur.	Ash.
1	0.81	20.640	74.023	0.507	4.02
2	0.67	21.360	74.284	0.435	3.251
3	0.78	21.680	73.052	0.688	3.80
4	0.71	23.400	72.218	0.532	3.14
5	0.765	20.090	74.779	0.666	3.70
6	1.10	23.070	71.199	0.611	4.02
Average,	0.806	21.707	73.259	0.573	3.655

These coals above given are from mines near Houtzdale, on the Beaver branch of the Moshannon, and represent the largest producing mines in the Clearfield steam coal region.

In the "Coal Regions of America,"† Mr. MacFarlane has discussed the Blossburg coals especially with reference to their use as blacksmith and steam coal. A part of this discussion, including his extract from Prof. Johnson, is reproduced below as embracing what is needed for a clear understanding of the position of the Blossburg coals.

"*Semi-bituminous coal*, in the sense in which we shall use the term to distinguish it from common bituminous coal, is that peculiar kind produced in the regions mentioned, which, while it yields coke and combustible gases,

*Report H. Second Geological Survey of Penn. 1874.

† Coal Regions of America, by James MacFarlane, Ph. D.

yet contains only 11 or 12, and always less than 18 per cent. of volatile combustible matter, and not less than about 70 per cent., and never more than 84 per cent. of carbon.

Whatever may be its useful qualities, it must be confessed it is in mere appearance inferior looking to almost any other kind of coal. As it comes from the mine, or in technical phrase, "the run of the mines," it consists of at least from one-third to one-half of fine coal, or what English miners call "dead-small," and some of it may be called dust. The large or lump coal is black, shining, and much more easily broken than anthracite, falling into irregular-sided cubical pieces, the cleavage being very much the same in a cross fracture as in the plane of stratification. It seldom cleaves into smooth, perfect cubical blocks of any size, like the Pittsburgh coal. It is decidedly dirty, cannot be touched without soiling the hands, and its whole merit and value consist in its useful qualities.

* * * It has a wider range in its use than any other kind of coal. For blacksmithing, for puddling and heating in rolling mills, and for steam, all kinds of coal are used, just as all sorts, however unsuitable or inferior, are to some extent used for household purposes; but the kind of coal which is invariably admitted to be by far the best adapted for the work of the blacksmith, or ironsmith (as he should properly be called), is what we are describing as the semi-bituminous coal. This is mainly owing to its great heating power, and its making what is called in the language of the trade, "a good hollow fire." The fine portions of the coal, which are generally used alone in this work, become adhesive and cemented together in burning into a compact body on the outside; the fire being confined to the interior of the mass, the coal not burning outwardly, but only around the iron which the smith is heating, and forming an arch lined with burning coals, into which the iron is thrust, while the outside presents no appearance of fire. This is not only a more economical fire, burning the coal only where it is needed, and protecting the workman from the heat of an outside blazing fire, which is so objection-

able, particularly in hot weather, but it makes a hotter fire by concentrating the heat in the interior, directly in contact with the iron, where it is needed.

In addition to this these semi-bituminous coals possess the very valuable quality, so indispensable for this work, and so important in all uses, of being free from sulphur. The great importance of this is but little appreciated in the Eastern States. As so much of the coal produced throughout the great Allegheny coal region is of good quality, we are only enabled properly to estimate its real excellence and its great purity after witnessing the masses of sulphuret of iron brought out of the mines with the coal, and much of it adhering to it and sold as coal in the States of Michigan, Illinois, and Missouri. For smithing, or for any work connected with the manufacture or use of iron, nothing is more injurious. In the New York, Philadelphia, Baltimore, Boston, and other Atlantic markets, no other coal is sold or used for blacksmithing but Cumberland, Clearfield, and Broad Top; while in the interior of the State of New York, in western Canada, or in all the Western or Northwestern States, every blacksmith uses Blossburg coal, which is the generic name by which all this kind of coal from northern Pennsylvania is called. As an instance of the distance to which this valuable fuel is carried, it may be stated that 75,053 tons were shipped in 1871 from Oswego and Buffalo to Canada and our own Western States. Chicago alone took 21,248 tons before the great fire, and had an insufficient supply, much of which was resold as far as Omaha, and shipped still further westward hundreds of miles toward the setting sun. The blacksmiths of Salt Lake City, in Utah, use Blossburg coal, and it is even carried in sacks over the plains and over the mountains, through the gold regions of our far western territories, to sharpen the tools of the miner several thousand miles from Blossburg, where it was mined. This is owing not to the absolute want of other coal, but to the western coal not possessing those peculiar qualities before described required for this business.

What has been said in regard to blacksmithing applies

to puddling, heating, and rolling mills. This work, however, is not done by a hollow fire, but by the passing over the iron of the heat and flame of the coal, requiring a strong coal of great heating power, burning with a flame so as to diffuse the heat from the furnace where it is burnt over the iron placed in the line of the draught, requiring also a coal free from sulphur and other impurities. All the puddling and heating furnaces from Troy, New York, to Buffalo use Blossburg coal in very large quantities. * * * * * *

There is also the important and useful attribute of this species of coal, which is not often referred to, but which is a high recommendation for its use in blacksmithing, in puddling, and heating in rolling mills, and in generating steam under boilers, giving it an advantage over anthracite. "The hydrogen of the gaseous part of the coal is a potent purifier, or remover of any sulphur with which either the coal itself or the iron may be contaminated. The excellence of the iron of the bituminous black band of Scotland is admitted to be due to the purifying influence of the hydrogen of its bitumen."—*Rogers*.

The superior quality of the wrought iron puddled and heated with semi-bituminous coal is well known, the reason being that the anthracite, unlike the semi-bituminous coal, contains but little hydrogen to form a chemical combination with and carry off the sulphur.

But the largest demand for Blossburg and other semi-bituminous coals is for the *generating of steam* in locomotive and stationary boilers. The qualities required for a good steam coal are various and are not very well understood.

"The question of the value of coals for the purpose of generating steam is, of course, mainly dependent on their heating power; that is, on the weight of water which a given weight of coal, burned under a given evaporating vessel, can convert into steam while undergoing combustion. But this is not the only circumstance requiring investigation, in order to decide their value.

The manner in which it burns, whether with much or little flame; the amount and character of its combustible ingredients; its facility or difficulty of ignition; the per-

fection of the combustion, or the proportion of the whole amount consumed to that of the combustible matter placed upon the grate; the concentration or diffusibility of its heat; the proportion of humidity and that of the sulphur which it may contain, with the consequent liability, under certain circumstances to undergo spontaneous combustion, are all points requiring attentive consideration. In addition to these, we have the question of the manner in which each coal behaves when coming to the temperature of ignition: its tendency to retain its original form; the nature and extent of change when any occurs, whether by simply cracking and disintegrating into angular fragments, or by enlarging the bulk, rounding away and obliterating the angles, and yet not agglutinating mass to mass; or, finally, by wholly changing its form and consistence, swelling to a great degree, and cohering so as to form a nearly continuous roof, and thus impeding the passage of air through the ignited coal. In some cases the question of the amount of solid matter which accompanies the gaseous products of combustion in the state of smoke, becoming soot upon the flues of the apparatus in which the combustion is conducted, is one of great practical importance. Of these incidental questions, the amount and character of the incombustible ingredients of different coals, is a point eminently deserving of notice. It indicates the deduction which must, in all cases, be made from the heating power of an equal weight of the coal, considered as pure combustible matter; it shows the extent and kind of labor requisite in managing the furnace; it warns us what to expect in regard to durability of grate bars, and the adhesion of scoria to those important appendages of the furnace. All these subjects must necessarially engage the attention of engineers and furnace-managers, and no little portion of the good or bad character of coal may be considered to depend on these circumstances. The relation of the incombustible ingredients of coal to each other is often such as to render the mixture fusible at the temperature of ordinary furnaces, or at least to be in a certain proportion reduced to a pasty coherent mass upon the grate, impeding the

passage of air, leaving another portion unvitrified, and capable of passing between the interstices between the bars. For different coals the proportion is very different, even when the combustion is conducted as far as practicable in the same manner and with the same intensity of heat."—*Walter R. Johnson.*

The tendency of semi-bituminous coal to melt and cohere so as to form a crust and, in part, impede the passage of air through the coal, might at first view be considered as an objection to its use for steam purposes. But * * * for the proper utilizing of the hydrogen gas given out in burning, a very large quantity of atmospheric air is required, so large that very few furnaces afford a sufficient supply to produce perfect combustion. Now, in burning bituminous coal which has not this melting or caking quality, the hydrogen gas is given out so rapidly, the coal burning altogether outwardly, that for the want of sufficient oxygen much of it passes off unconsumed, and a large part of the heating power of the coal is lost, whereas with the semi-bituminous or caking coal the gas is partially retained by the formation of the crust, and is given out more gradually, the crust acting the part of a temporary gas holder, from which the fireman, with his poker can, as occasion requires, by breaking the crust, allow the gas to escape in such quantities that it may unite with the limited supply of oxygen. This caking quality is very valuable in a locomotive fuel, where the draft is so strong that an adhesive coal is preferred, and it admits of the use of grate-bars with wider air spaces than can be used with other coal that would be liable to fall through the grates, which is attended with a loss of fuel.

"The Superintendent of the United States Armory at Springfield, Massachusetts, has recently been conducting a series of experiments to test the value of certain kinds of coal as steam generators. Each variety of three different classes of coal was used for six consecutive days in raising the steam for the engine of the establishment, with the following reported results: Of the Lackawanna, or hard anthracite, 4.01 pounds per horse power were used per hour; of the Pittston, or softer anthracite, 4.02 pounds were used;

and of the Cumberland or bituminous coal of Maryland, 3.03 pounds were used. At the Springfield Armory, the Lackawanna coal cost $8 50 per gross ton, the Pittston $7 85, and the Cumberland $9 10. From these data it is calculated that the cost, per horse power, is 15 mills for Lackawanna, 14 mills for Pittston, and 12 mills for Cumberland; and it is therefore alleged that bituminous coal is the more economical fuel as a steam-generator, making more heat and creating more power per pound and per cent. of cost than the harder coals.

This has also been done at Colt's Armory in Hartford; and after careful experiments it was found that for steam-generating purposes the Cumberland coal was better and cheaper than the anthracite, whether compared ton for ton or by the relative cost of the two."

Probably there is no better and more succinct statement of the requisites of a good steam coal than is given in the Rogers' Final Report of Pennsylvania Geology. It, of course, embodies all the results of W. R. Johnson's experiments for the Navy Department.

"1. It should possess a high absolute evaporative power.

2. It should, at the same time, as far as is compatible with the foregoing property, kindle readily, and burn with great celerity, generating a large body of steam in a short time.

3. It should be easily managed, and steady in its combustion, and to this end its ashes or earthy matter should tend, as little as possible, to choke the draught of the grate by fusing, even at an extreme heat, into an adhesive clinker.

4. The fuel should be free from any excess of incombustible matter, as this, all other things being the same, will materially impair its efficiency, and its ashes should produce but little clinker.

5. It should be exempt from any considerable amount of sulphur, for this tends to corrode the flues, and is otherwise detrimental.

6. Whatever volatile matters it possesses should not be bituminous, but should be in the condition of the free gases,

susceptible of ignition or disengagement without smoke, and these volatile matters should not exist in any greater amount than will suffice to give rapidity of combustion to the fuel. Any larger proportion is at the expense of its heating power.

7. A fuel should not be too cohesive and refractory on the fire, nor yet too tender and divisible. In the one case its combustion will be slow and irregular, and in the other it will be still slower for the want of the requisite draught. A certain degree of spontaneous frangibility, such as is shared by some of the less-resisting anthracites, and by many of the firmer semi-anthracites, appears from practice and experiment to be the structure best suited to extreme vigor and steadiness of combustion.

8. For certain purposes of domestic consumption, coals should be capable of sustaining a mild and steady combustion, and of remaining ignited at a low temperature with a comparatively feeble draught.

9. For certain uses it is important that a coal should unite with a high evaporative power such a degree of density and structure combined, as will enable it to contain a relatively large amount of carbon in a given space. This capability of being economically stowed or packed away, is a point of daily increasing consideration. The difference between the least and the most stowable anthracites is as much as 16 per cent., and between the closer packing anthracites and the lighter and more open bituminous coals, it even exceeds 20 per cent.

10. It is likewise desirable that a coal should possess sufficient tenacity in the lump, to bear the abrasion incident to its transportation, without serious waste by reduction to fine coal.

These are the principal qualities in coals which materially influence their economical value. No one variety will ever be found to unite them all, for some of them can hardly co-exist in a high degree in the same specimen. The relative worth to be assigned to these several desiderata, is itself variable with the uses to which the fuel is to be applied. But having a specific application in view, it is easy

to ascertain what union of compatible qualities will insure to a coal the highest possible efficiency. This once determined on, the records of judiciously conducted practical experiments will then prove the proper guide in selecting the kinds required."

Classification of Coals.

In classifying the coals of Pennsylvania for the Report of the First Geological Survey, Prof. H. D. Rogers tabulated them thus:

- ANTHRACITES,
  - Hard Anthracite.
  - Semi, or Gaseous Anthracites.
- COMMON BITUMINOUS COALS,
  - Semi-bituminous Coals,
    - Semi-bituminous Cherry Coal.
    - Semi-bituminous Splint Coal.
  - Bituminous Coals,
    - Caking Coal.
    - Cherry Coal.
    - Splint Coal.
- HYDROGENOUS, OR GAS COALS,
  - Cannel Coal.
  - Hydrogenous Shaly Coal (Torbanehill, &c.)
  - Asphaltic Coal (Albert mine.)

Anthracites—Volatile matters below 6 per cent.

Semi-anthracites—Volatile matters below 10 per cent.

Semi-bituminous—Volatile matters between 12 and 18 per cent.

Bituminous—Volatile matters above 18 per cent.

This classification was found convenient for commercial purposes, and has been, therefore, in very general use.

In a paper upon coals,* Prof. P. Frazer, Jr., has pointed out how, in any scientific classification, the consideration of the accidental impurities (the water, ash, and sulphur,) will totally destroy the possibility of grading the coal according to its true rank, that is the proportion of volatile hydrocarbons to fixed carbon.

He cites the following example: "As an illustration of some of the bad effects of such a system (at least for systematic classification) let us suppose that we have a pure coal corresponding to each of the limits which Professor Rogers sets for bituminous coals, viz: 1st. Fixed carbon, 84 per cent., volatile hydrocarbons, 12; that is to say, one part

* Paper read before the American Institute of Mining Engineers by Persifor Frazer, Jr.

of volatile hydrocarbons to 7 parts of fixed carbon. 2nd. Fixed carbon, 52, and volatile hydrocarbons, 48=13:12. If we mix the first of these materials with various weights of impurities, we shall have substances whose constitution is expressed in the following table:

	I.	II.	III.	IV.
Impurities, per cent., ...	20	28	36	44
Fixed carbon, per cent., ...	70	63	56	49
Volatile hydrocarbons, per cent., . . .	10	9	8	7

In the second case the table would be:

	I.	II.	III.	IV.
Impurities, per cent., ...	0	25	50	75
Fixed carbon, per cent., ...	52	39	26	13
Volatile hydrocarbons, per cent., . . .	48	36	24	12

Yet the *fuel* portion of all the mixtures in the first table is the same, viz: a bituminous coal of the composition C: V—H. C:: 87.5 : 12.5, and that of all the mixture in the second C: V—H. C:: 52 : 48. The foreign impurity is the only item of difference between the analyses of each table."

After alluding to the fact that Walter R. Johnson had (in 1844) adopted the true method by classifying his coals according to the ratio of fixed carbon to volatile combustible matter, Prof. Frazer suggests the following classification:

	C / V—H. C.
Hard, dry anthracite, ...	100 to 12
Semi-anthracite, ...	12 to 8
Semi-bituminous, ...	8 to 5
Bituminous, ...	5 to 0

An average of eight analyses of the Bloss Vein coal from the Blossburg Coal Basin gives the following result:

Water,	1.465
Volatile matter,	19.741
Fixed carbon,	68.974
Sulphur,	.686
Ash,	9.134
	100.000

This may be taken as about fairly representing the Blossburg coal as shipped from the basin.

The coal has always been classed as *semi-bituminous*, and is altogether sold and used as a coal of this class.

Yet it is slightly beyond the limit of volatile hydrocarbons assigned to semi-bituminous coals, taking Prof. Rogers definition that coals are called semi-bituminous when they have anywhere from 12 to 18 per cent. of volatile hydrocarbons, 70 to 84 per cent. of carbon, and the balance water, sulphur, and ash ; and are called bituminous coals whenever they exceed the above percentage of volatile hydrocarbons.

It has been shown above by Prof. Frazer how exceedingly loose and unscientific any definition is which brings in the accidental and varying impurities ; and that scientific classification demands their exclusion.

Yet while scientifically speaking a coal is as much a true coal whether it contains 2 per cent. or 22 per cent. of impurities, yet in a commercial sense, over those regions where a comparatively pure coal is easily obtainable, a coal ceases to be a *coal* when it contains above 15 to 20 per cent. of impurities.

That is, in the language of the business world, coal means *merchantable coal ;* and the ash, sulphur, and water, which are, scientifically speaking, mere accidental impurities, are, in the business view, the features of its constitution most carefully to be considered.

To define the true character of the coal more strictly, in leaving out the impurities, the relationship of volatile hydrocarbons to fixed carbon in the Bloss vein coal is 1 to 3.4939.

This ratio differs decidedly from that assigned to the Blossburg coal by Prof. W. R. Johnson. He made the relationship of volatile hydrocarbons to fixed carbon as 1 to 4.946.

There is here a curious discrepancy between the complete and accurate series of analyses of Mr. McCreath and the character of the Blossburg coal as given by Prof. Johnson.

The Blossburg coal, as examined by Prof. Johnson, was mined by the Arbon Coal Company, at Blossburg, from a three foot coal bed; was mined in January and packed for shipment May 12, between these dates lying exposed. It yielded on analysis:

Moisture,	1.339
Sulphur,	0.853
Other volatile matter,	13.927
Earthy matter,	10.773
Fixed carbon,	73.108
	100.000

This doubtless represented fairly the character the character of the coal from the Blossburg mine of the Arbon Company.

But all the analyses made by Mr. McCreath of the coals from Fall Brook, Morris Run, Arnot, and Antrim agree closely with each other. The variations in character are trifling, and the average of them all is to give the Blossburg coal, as stated above, an average of volatile hydrocarbons to fixed carbon of 1 to 3.4939.

Far more surprising than the discrepancy noted above is the record of an analysis, by Prof. Walter R. Johnson, of the "Bear Creek, Blossburg" coal. It is in the table of analyses of the Roger's Final Report of Pennsylvania.

The analysis shows:

Coal columnar, somewhat compact, thin seams of charcoal, lustre jet black.

Vol. matter in 100 parts,	32.00
Fixed carbon, do. do.	68.00
Earthy matter, do. do.	5.20

Taking the volatile matters (which presumably include the water and sulphur, and thus injure the accuracy of the result) and the fixed carbon (32:68) the proportion stands as 1 to 2.125.

By comparing these two widely divergent analyses of Prof. Johnson with the comparatively complete and very closely agreeing sett of analyses of Mr. McCreath, it is

easy to see how great may be the injustice and error in reasoning as to average character over considerable areas by any single analysis of one specimen.

Prof. Johnson's analyses were doubtless perfectly accurate of the specimens sent to him, yet neither of them gave anything like a fair judgment of what is really the Blossburg coal as it now goes to market.

The statistics of the coal production of the Blossburg, McIntyre, and Barclay mines for the years 1871–1877 are thus given by James Macfarlane, Esq., the General Agent of these united companies :

Annual Production of Semi-Bituminous Coal in Northern Pennsylvania, for seven years, in Tioga, Bradford, and Lycoming Counties, Pa. Compiled by James Macfarlane, Esq.

Years.	Tioga County.			Lycoming County.	Bradford County.			Total annual production.
	Fall Brook Coal Company.	Morris Run Coal Mining Company.	Blossburg Coal Company.	McIntyre Coal Company.	Schrader Coal Company.	Towanda Coal Company.	Fall Creek Bit. Coal Company.	
1871, ...	232,632	385,994	196,453	106,130	. . . . .	249,240	129,090	1,299,544
1872, ...	233,694	318,079	297,489	171,427	. . . . .	263,960	118,882	1,403,531
1873, ...	312,466	357,384	321,207	212,462	. . . . .	252,329	85,315	1,541,163
1874, ...	258,192	249,438	255,086	138,907	100,219	215,572	21,281	1,238,695
1875, ...	190,347	164,506	226,420	164,504	157,686	200,424	18,529	1,122,416
1876, ...	217,347	197,698	201,939	208,701	200,795	160,343	. . . . .	1,186,823
1877, ...	199,510	181,001	221,734	183,715	175,757	164,344	. . . . .	1,126,061
	1,644,188	1,854,100	1,720,328	1,185,846	634,457	1,506,212	373,102	8,918,233

The following table shows the shipments of Clearfield Co. (Penn.) coal for the years 1873–1877. The statistics are furnished by Mr. Shillingford, Secretary of the Kittanning Coal Company:

1873,	612,075	net tons.
1874,	665,214	"
1875,	927,867	"
1876,	1,218,861	"
1877,	1,372,153	"

While this enormous trade in Clearfield coal has been growing with such rapid strides, the Cumberland (Maryland) coal region has steadily decreased its shipments, from 2,674,101 gross tons in 1873 to 1,574,339 gross tons in 1877. Local causes, strikes, and disputes concerning shipment rates have contributed to this decreased shipment from the Cumberland Basin; and while this has of course assisted the Clearfield trade, yet the chief reason for the increase of tonnage is the extraordinary cheapness with which clean coal can be put upon the cars in the Houtzdale region.

Blossburg Coke.

The analyses of cokes made at Arnot are given on page 183, and the description of their appearance and strength on page 185.

A number of years ago some partial and probably unskilled attempts were made to coke the Bloss coal. The result was a failure; and for many years it seemed to be agreed that nothing could be done successfully in the way of coking it.

The recent experiments made at Arnot have demonstrated that the slack coal, coked in the Beehive Oven, for 48 hours, watered in the oven, &c., as is customary in the Connellsville region, will produce a firm, coherent, ringing coke, of excellent character, and strong enough to bear the burden in a furnace stack of 60 feet in height.

Already more coking ovens are being built at Arnot; and it is doubtless only the commencement of a large and permanent trade in coke for the supply of New York State.

In connection with the question of coking, the analyses

of the coals, as given in the detailed report, bear upon the percentages of sulphur volatilized in coking.

Considerable attention has been given to this question, and it has been maintained usually that the *condition* of the sulphur in the coal was the important factor—that "free sulphur" would nearly all pass off in coking, while sulphur combined with iron would remain in the coke.

A laboratory coking of Barclay coal gave:

Sulphur taken up by iron,	.192
Free sulphur,	.584
Sulphur volatilized by coking,	27.190 per cent.
Volatile matter in coal,	17.110

A laboratory analysis of some Seymour Vein coal gave:

Sulphur taken up by iron,	6.352
Free sulphur,	.504
Sulphur volatilized by coking,	35.15 per cent.
Volatile matter in coal,	19.830

Another analysis of laboratory coke from the Seymour Vein coal gave:

Sulphur taken up by iron,	1.007
Free sulphur,	.788
Sulphur volatilized by coking,	31.92 per cent.
Volatile matter in coal,	20.105

A laboratory coke from Bloss Vein coal gave:

Sulphur taken up by iron,	.152
Free sulphur,	.431
Sulphur volatilized by coking,	14.750 per cent.
Volatile matter in coal,	18.570

Another laboratory analysis of Bloss Vein coal gave:

Sulphur taken up by iron,	.152
Free sulphur,	.409
Sulphur volatilized by coking,	15.12 per cent.
Volatile matter in coal,	18.540

A laboratory coke made from Bear Creek coal gave:

Sulphur taken up by iron,	.280
Free sulphur,	.445
Sulphur volatilized by coking,	27.44 per cent.
Volatile matter in coal,	20.965

It will immediately be seen how utterly these analyses disagree with any theory ot the volatilization of all, or nearly all, the "free sulphur" by coking.

In the first analysis, with 75 per cent. of the sulphur as "Free Sulphur," and 25 per cent. of sulphur combined with iron, 27.19 per cent. of sulphur were volatilized.

In the second case, with only 7 per cent. "Free Sulphur" and 93 per cent. sulphur with iron, 30.15 per cent. of sulphur were volatilized.

In the third case, with 44 per cent. "Free" and 56 per cent. with iron, the volatilization was 31.92 per cent.

In the fourth case, with 74 per cent. "Free" and 26 per cent. with iron, the volatilization was 14.75 per cent.

In the fifth case, with 73 per cent. "Free" and 27 per cent with iron, the volatilization was 15.12 per cent.

In the sixth case, with 61 per cent. "Free" and 39 per cent with iron, the volatilization was 27.44 per cent.

Thus more than twice the percentage of sulphur was volatilized from a coal holding only 7 per cent. of "Free Sulphur" than from a coal holding 74 per cent. of "Free Sulphur." In the face of such figures it is impossible to cling to any theory of volatilizable free sulphur; and it seems as though the condition of the sulphur in the coal could be of no possible consequence in informing us what would be the percentage of sulphur to be driven off in coking.

Although there has not yet been gathered sufficient facts to warrant any definite opinions upon the subject, yet the general tendency of them all is to point to a relationship between the percentage of volatile matter and the percentage of sulphur expelled in coking.

In the numerous coke and coal analyses which have been given in previous reports, where the general average of the volatile matter of the coal was 30 to 35 per cent., the average volatilization of sulphur in coking averaged fully 35 per cent., whether in laboratory tests or in practical coking in large quantities in Beehive Ovens.

The average percentage of volatile matters of the coals just named above is 19.18; and the average percentage of sulphur volatilized in coking is 24.43.

Chapter XIV.

The Gaines Coal Basin in Tioga County and on Pine Creek in Potter County.

It has been the prevalent opinion for many years that no coal, or very little, existed in Tioga county except in the synclinal axis of the Blossburg Coal Basin.

This is clearly an error, for coal beds of the Lower Productive Measures are now opened and worked in Gaines township, Tioga county, in the next great synclinal north of the Blossburg Basin, from which it is separated by a broad anticlinal valley.

The exact course of the "Gaines Basin" is thus described by Mr. Sherwood, who has carefully followed out the anticlinals and synclinals of Tioga and Bradford counties.

* * * "Its centre line enters Tioga from Bradford county, near the southeast corner of Jackson township; crosses Tioga River at the mouth of Mill Creek; Crooked Creek, near Potter's Hotel; and enters Potter county on the north side of Pine Creek. At the line between Tioga and Rutland townships this basin, on its highest knobs, catches the Millstone grit, which is the foundation or "bottom rock" of the true coal measures. This rock possesses very marked characters of its own, which serve to distinguish it from every other bed. At some points in this basin it contains pebbles of quartz; at others it is a hard, white, quartzose sandstone, excellent for the manufacture of glass, and having a very uniform thickness of about thirty feet. The hills have suffered such erosion from the waters of the Tioga, Mill Creek, Crooked Creek and tributaries, that we do not meet with this rock again on going west until after

we cross Norris Brook, west of Niles Valley, where it again caps the hills. But here the basin begins to widen and deepen to the southwest, so that on reaching "the barrens" at Long Run, instead of capping the hills, it is low enough to be itself capped by over one hundred and ninety feet of coal measures."

As above stated, the coal measures first catch in this basin in the vicinity of Long Run, Gaines township.

When this region was examined (November, 1877,) it was not opened up in such a manner as to afford a complete vertical section of the measures and a special examinations of all of the coal beds.

The region had been opened up a year before for a private examination by Mr. Sherwood, who reported the facts to the owners. These openings could not be seen and measured, except in part, when examined in November, and Mr. Sherwood's statements will therefore be re-produced in this chapter, concerning facts observed by him in his survey.

In the centre of the basin, where the highest geological measures are caught, a sandstone, thin bedded usually and much current bedded, 35′ thick, makes the hill crest.

Under it comes the upper Coal bed, called the "*Hurd Coal bed*" locally; it was mined many years ago, but the opening is now closed. It is *reported* to have yielded 22 inches of coal of good character, having been worked to a considerable extent and hauled many miles for blackmith's use.

But it could not be measured, nor could any specimens be procured for analysis, to show its character.

The next coal opened below the Hurd Coal, called locally the "*Knox & Billings*" coal, is the bed now mined for local use in the region.

There would seem to be about 20 feet of interval rock between the two beds, slates and shales. In the absence of opportunity to examine the Hurd Coal it seemed at first as though the two beds might be identical, but there is apparently a difference in covering rocks which justifies their separation by about 20 feet of interval.

A mine is opened on the *Knox & Billings* Coal bed, 2 miles from Gaines P. O.

The coal is picked or blasted down from roof to floor clean. It has no regular and persistent slate parting. Some irregular small lenticular masses of slate show in the bed.

Where examined, fully 100 yards in under cover, the coal was yet rusty, apparently from roof cracks, the rust and infiltered clay showing on the butt-face.

Though the coal is tolerably compact yet it breaks up a great deal in mining. It is cuboidal, with but little mineral charcoal, only a small show of pyrites, and jet black on fresh fracture.

The average thickness of clean coal from roof to floor, where measured, was about 3 feet. It is said to run from that up, sometimes considerably larger. But 3 feet to $3\frac{1}{4}$ feet is probably a fair average, or 5000 tons to the acre, taking broad areas in question.

The coal is much used locally by blacksmiths, and is hauled many miles for the purpose. It makes a hollow fire, with great heat; any welding can be done by it, and it holds fire well in the forge fire.

The coal is screened at the mine, and several hundred tons are hauled away annually for use in the valley to the northward. No attempt has been made to test it for coking purposes.

An average specimen of the Knox & Billings Coal was forwarded to the Laboratory of the Survey and yielded on analysis (McCreath):

The coal, generally coated with a yellowish white silt, has a deep black shining lustre on fresh fracture, is rather compact, showing numerous partings of mineral charcoal.

The coal analyzed seemed quite wet.

Water,	3.260
Volatile matter,	27.860
Fixed carbon,	60.421
Sulphur,	.804
Ash,	7.655
	100.000
Coke, per cent.,	68.88
Color of ash,	Reddish gray.

The high percentage of water is due probably to nothing more than the specimen having been soaked *in transitu.*

The analysis shows a pure and good coal. It is however more nearly approaching to a gas coal than to a steam coal; the volatile matters being almost 28 per cent., which is nearly the average percentage of the Connellsville coal in Fayette county, or of the Reynoldsville coal in Jefferson county, Penn.

A drift has been run into the outcrop of a *coal bed which lies 40 feet below* the Knox & Billings coal.

The mine runs in to the south-east and drains.

The coal ran evenly and on the level for about 30 yards. It then plunged down to the southeast for several feet, and the water rose and drowned the opening.

The coal, therefore, could only be seen and measured on the south side of the main entry, and about 20 yards in from the crop. It showed:

Roof, clay slate,	——
Coal,	2′ 4″
Floor, massive sandstone,	——

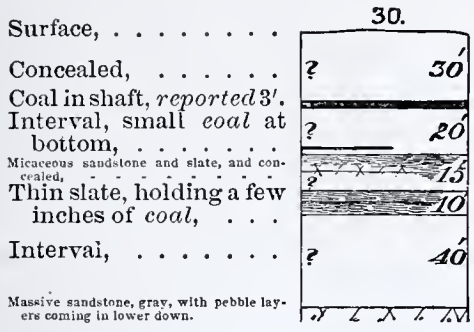
The coal where examined was rather rotten and dirty; a variable slate layer, ranging from $\frac{1}{2}''$ up to 2″ or more, occurs 1 foot above the floor; the massive sandstone floor, is 4′ thick, filled with impressions of fossil plants.

No fair specimen of the coal could be procured for analysis. At the face of the mine, the coal seemed rather harder and more compact than the Knox & Billings coal.

But the roof (clay slate) seemed treacherous, the floor of massive sandstone is very abnormal, and from the uneasiness of the coal in the short distance already opened, it would seem likely to prove an uncertain and deceptive bed.

It is reported that the coal was shafted down to near the present drift and found 4 feet thick. This, of course could not now be seen.

An imperfect section made about 1 mile from the Knox & Billings mine gave this:


30.
Surface, ... —
Concealed, ... 30′ 0″
Coal in shaft, *reported* 3′.
Interval, small *coal* at bottom, ... 20′ 0″
Micaceous sandstone and slate, and concealed, ... 15′
Thin slate, holding a few inches of *coal*, . . . 10′
Interval, ... 40′
Massive sandstone, gray, with pebble layers coming in lower down.
Total, ... 115′ 0″

The above imperfect facts represent all that were showing at the time of the examination.

The Knox & Billings coal is clearly the valuable bed of the region.

Over how great an area this bed extends could only be determined by a careful and prolonged examination. It occurs so near to the hill tops that a slight change in the geological structure would suffice to throw out or take in hundreds of acres. That it covers some considerable area is, however, very clear.

Report of Mr. Sanderson Smith.

This region was examined by Mr. Sanderson Smith, who under date of November 9, 1875, records the facts observed by him. The map which accompanied Mr. Smith's report is appended to this volume.

"Eight coal beds have so far been made out, three of which have been opened to some small extent, while a fourth may possibly prove workable.

The uppermost of these, which has a thickness of 22 inches, is the one upon which nearly all the old openings from which a supply of coal for the neighborhood was obtained in past years, were made. In 1868, when I made my first visit to the tract, an opening known as "Hurd," on Warrant 2,300, just east of the east line of 2,299, furnished all the coal then mined for sale. This was of very good quality, but the thinness of the bed, together with the fact that it is so near the highest level of the hills as to

probably underlie a very small territory, renders its value small. No coal is at present obtained from it.

Eight or nine feet below this is a bed of coal a foot thick, and three feet below this one of eleven inches. Of these, I have seen nothing but the outcrops. * * * *

Six to eight feet lower down, or twenty-one feet below the 22-inch or "Hurd Vein," comes the so-called "three-foot" or "Knox and Billings" bed, which I am inclined to consider the most valuable one yet discovered.

* * * A level has been driven easterly from the east bank of Benn Gully, and chambers excavated. At one point in this level I measured 4 feet 6 inches of good coal, with apparently only one inch or less of shale, and no visible pyrites or sulphur. Further in it was at one place only 2 feet 9 inches thick, and then widened again. I am inclined to think that its average thickness is likely to exceed rather than fall short of three feet. The quality of this coal is exceedingly good for all domestic purposes—for blacksmith's use, for the generation of steam, &c. * *

In common with all semi-bituminous coals of this region it makes a very friable coke, and is, therefore, not suited for blast furnace; and the same reason will probably prevent its extensive employment in gas making, as few gas companies are willing to employ a coal the coke from which is of no commercial value. * * * * *

Eleven feet below the "three-foot" seam, or thirty-five feet below the 22-inch bed, is a bed of about 28 inches in thickness. This bed I made an examination of in 1868, and did not then form a very favorable opinion of it. Another opening has since been made upon it, and it there presents a much better appearance, and would probably look still better if I had been able to examine a freshly cut surface, as no work has for a good while been done upon it. * *

Twenty-seven feet below this, or sixty-three feet below the 22-inch bed, is the so-called "four-foot" bed. This has been opened by a level directly below the Knox and Billings opening. In this it seems to have an average thickness of 2 feet 9 inches; but in a shaft put through it at a point not far off I am informed that it was four feet thick. The coal

from this bed seems to be of excellent quality, a little harder than that of the "three-foot" seam, and apparently applicable to exactly the same purposes, and will probably bear distant transportation somewhat better. When tried in the blacksmith's forge it gave an excellent fire. * * *

Eighteen feet below this bed is a ten-inch bed, and twenty-five below, or 91 feet below the 22-inch bed, comes a bed or series of beds, to which the name of the "five-foot" seam has been commonly given. At the "Bellows shaft," a little north-east of the Knox & Billings opening, a shaft of 14 feet depth passed through it, and a short level was driven from the bottom of this. Here the series consisted of

Coal,	1′ 0″
Fireclay,	1′ 6″
Coal,	4″ to 0′ 5″
Fireclay,	1′ 6″
Coal,	1′ 0″

Or two feet four or five inches of coal out of a total thickness of five feet four inches. At a short distance South of this, in an open cut, but where I saw no reason to think that the arrangement of the bed had been materially altered by external influences, only the upper foot of coal exists, the lower three or four feet consisting entirely of fireclay; while in a boring at the mouth of the "four-feet" level, the succession of beds was, I am told, almost exactly the same as at the "Bellow's shaft." The coal from these different openings appeared, as far as I have seen it, to be of good quality. The value of this sett of beds must, as yet, be considered quite uncertain. It is certainly not workable at the points now opened, but it is quite possible that in some other part of the lands, a large proportion of the thickness, perhaps the whole, may be found to be coal.

About 65 feet below this series of beds, or 161 feet below the 22-inch seam, comes the Conglomerate, which forms the apparent base of the Coal measures." * * * * *

These facts, as detailed by Mr. Smith, agree on the whole with the statements already made as to what is now show-

ing. That is that the Knox & Billings bed is a good bed, averaging three feet of coal; that the bed 40 feet below it *may* run to three feet of coal, and will underlie a larger acreage; and that the lower or so called "five-foot" coal may be dismissed from any calculations until it has been shown to be coal, and not coal and fireclay.

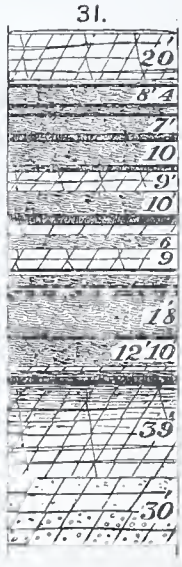
Report of Mr. Andrew Sherwood.

This same region was examined by Andrew Sherwood, Esq., of Mansfield, Tioga Co., who reports (under date of Jan., 1877,) the following facts as showing when examined by him:

"The following section, as ascertained by Mr. Baker, will show the order and thickness of the beds which constitute the one hundred and ninety feet:

. . . . . .

Section of Coal Measures at "the Barrens."



No.		
1.	Brownish quartzose sandstone, weathering white, and mistaken by some for the Millstone Grist; contains carbonized stems of plants; caps the mountain	20′ 0″
2.	Black slate,	2′ 0″
3.	*Coal*,	1′ 8″
4.	Dark-colored shale,	8′ 4″
5.	*Coal*,	1′ 0″
6.	Light and dark-colored shale,	3′ 3″
7.	*Coal*,	0′ 11″
8.	Dark, sandy shale, with carbonized stems of plants,	7′ 0
9.	*Coal*, varies from 2′ 0″ to 5′ 2″	3′ 0″
10.	Dark-colored shale,	10′ 0″
11.	*Coal*,	2′ 5″
12.	Brownish-gray and light-colored S. S.,	9′ 0″
13.	Dark-colored shale,	10′ 0″
14.	*Coal*,	4′ 0″
15.	Gray and light-colored sandstone,	4′ 0″
16.	Brownish and dark-colored clay shale,	6′ 0″
17.	Gray and light-colored sandstone,	9′ 0″
18.	*Coal*,	0′10″
19.	Fireclay,	2′ 0″
20.	Dark-colored shale,	4′ 0″
21.	*Coal*,	1′ 9″
22.	Fireclay,	1′ 9″
23.	*Coal*,	1′ 9″
24.	Dark-colored shale,	18′ 0″
25.	*Coal*,	0′ 4″
26	Dark-colored shale,	12′10″
27.	White sandstone,	1′ 2″
28.	Black slate,	2′ 0″
29.	*Coal*,	4′ 8″
30.	Fireclay,	2′ 0″
31.	Brownish sandstone, becoming a dark, sandy, slaty rock towards the top,	39′ 0″
32.	Millstone Grit, or hard, white quartzose, sandrock and conglomerate,	30′ 0″
	Total,	223′ 8″

* * * * * * Nos. 3, 5, and 7 are too thin to be considered of much importance. No. 3 is known as the "Hurd Vein." * * *

No. 9 varies in thickness from two feet and a half to five feet and two inches [Knox and Billings bed]. It is now worked to the extent of five hundred tons annually. The coal is very pure, of a dull lustre, burns with a bright

flame, and is not surpassed by any coal in Tioga county for domestic use. For some purposes in the working of steel it is said to be taken on wagons a distance of seventy-five miles.

Mr. Baker says he dug through No. 11, but the shaft having become filled up, I did not see it.

No. 14 I saw and measured myself. A drift has been cut into it for a distance of several rods. Here appears to be a vein of coal, four feet thick, of good quality, and underlying a large territory. * * *

No. 18 is too thin to be of any account.

Nos. 20 and 21 were cut through in a shaft, and the coal is said to be of good quality, but in order to work them the parting of fireclay (which may be local) would have to be mined also.

No. 29 I did not see, and therefore cannot vouch for its existence, but Mr. Baker claims to have drilled through it, and I see no reason to doubt the truth of his statement, for it is in the horizon of the three foot vein which I did see and measure in this same basin up the West Branch of Pine Creek. * * * *

The value of these coal beds is greatly enhanced from the fact that they dip slightly to the North-west on the South side of "Benn Gully," while on the North side they dip slightly in the opposite direction, or to the South-east. This is most fortunate, as Benn Gully is a branch of Long Run, and offers a good opportunity of reaching there with a railroad." * * *

Taking the facts as stated by Mr. Sanderson Smith, the facts observed personally by Mr. Sherwood and recorded by him, and the observations made during the examination for the State Geological Survey in November, 1877, and it seems clear that the Gaines Basin derives its chief importance and value from the presence of the Knox & Billings Coal bed.

The coal is clean and pure, and should be an excellent domestic fuel and a valuable steam coal; but if Mr. Smith's statement as to its non-coking character be borne out by tests, it will materially interfere with its sale to gas com-

panies—a sale which the high percentage of volatile matters would certainly secure to it, if only a valuable residual coke could be obtained from it.

The bed 40 feet below the Knox and Billings bed underlies a much larger area, and if it prove to average 3 feet in thickness, or even 30 to 33 inches, would add much to the value of the basin. It is as yet not sufficiently developed to warrant anything more definite in the way of assertion or calculation.

In character, this lower bed gives every evidence of coming up to a high standard.

The 22-inch (Hurd coal) bed, which lies above the Knox and Billings coal, may be dismissed as too small to work for shipment to market, though of good character and very regular and persistent. It only underlies the highest hill tops.

The mass of coal and fireclay called the "five-foot" bed, so far as opened up, is of no commercial value so long as it carries so much clay parting to its 2½ feet of coal.

Should it ever be opened as a clean coal bed, it would be of much consequence, and underlie the whole coal basin indicated on the maps.

The lower large coal (called 4 feet 8 inches on Mr. Baker's section) cannot enter into any estimate of the basin. It has never been shown to any of the persons examining, and from actual observation, therefore, both its size and character are unknown.

In view of the proximity of this basin to the great market of Western New York, the certain presence of a three-foot coal of good character, with another good bed probably as large, gives great importance and value to the region in the vicinity of Gaines Post Office.

The general limits of the coal are from Asaph's Run on the East to Long Run on the West. The South line is at least 1 to 1½ miles north of Pine Creek, while the North line—only approximate and not from instrumental surveys—is seen on the map to sweep around so as to narrow the basin within a width (North and South) of 1½ miles, more or less. More definite details could only be exactly ascertained by running out the outcrop lines.

It is reported that the Conglomerate of XII with the lowest coal or coals on top of it, is caught in the extreme hill tops west of Long Run, and on to Phœnix Run, and that a coal bed was once opened. This coal was not seen, but Mr. Baker reports the fact. It could cover only a small area, accessible with difficulty, and is of little practical consequence.

There appears to be no coal at all caught on the hills in the centre of the synclinal axis from Phœnix Run on westward to the Forks of Pine Creek.

But coal comes into the hills in the synclinal axis on Pine Creek, between the Main branch and the West Branch.

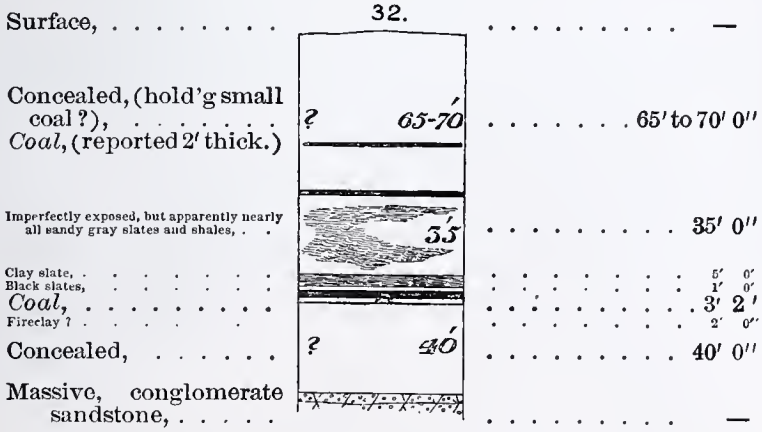
Pine Creek, Potter County.

The Lower Productive Coal Measures are caught in the hills, on the continuation of the Gaines Coal Basin to the westward, in the country lying between the West Branch of Pine Creek, and the Main or East Branch of Pine Creek, in Potter county.

Coal is opened on the outcrop for examination at numerous places, and on Whittemore run it has been drifted into until solid coal was worked under good cover.

The coal opening is on the west side of the East Branch of Whittemore run, and is 690 feet (by barometer) above the Rorybacker house, on the West Branch of Pine creek at the mouth of the run, and about 2160 feet above tide.

The vertical section of the measures on Whittemore run as imperfectly exposed was thus compiled:


32.
Surface, ... —
Concealed, (hold'g small coal?), ... ? 65-70' . . . . . 65' to 70' 0''
Coal, (reported 2' thick.)
Imperfectly exposed, but apparently nearly all sandy gray slates and shales, . . 55' . . . . . 35' 0''
Clay slate, ... 5' 0'
Black slates, ... 1' 0'
Coal, ... 3' 2'
Fireclay ? . . . . . 2' 0''
Concealed, ... ? 40' . . . . . 40' 0''
Massive, conglomerate sandstone, ... —
Total, ... 156' 2''

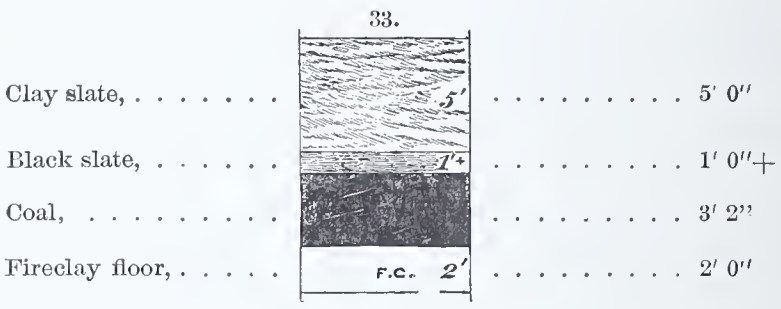
The coal reported in the upper part of the above section was not seen at all, nor has it been opened.

The coal 40 feet above the 3′ 2″ coal was struck in a 10 foot shaft. It is called a 2 foot bed. The pieces of it lying on the surface would indicate a hard, compact, firm, cuboidal coal, high in volatile matters.

The chief bed of the region, and the only one opened up, is the coal 40 feet above the conglomerate.

The gangway upon it runs in north 80° west. The coal dips plainly to the south-west, and the butt of the coal is north-west.

The mine was partially drowned, and the coal as examined only about 15 yards in from the crop measured thus:



There are no regular slate partings in the coal bed, only occasional lenticular masses.

The coal is hard, mines out well, is jet black in lustre on fresh fracture, cuboidal in structure.

An average specimen was forwarded to the laboratory of the survey, and yielded on analysis (McCreath):

The coal, generally coated with silt, has a deep black, shining lustre on clean fracture; it is compact and firm, and has a few thin partings of slaty coal.

The coal when analyzed seemed quite wet.

Water,	3.070
Volatile matter,	30.970
Fixed Carbon,	55.140
Sulphur,	.975
Ash,	9.845
	100.000
Coke, per cent.,	65.96
Color of ash,	Cream.

The high percentage of water in the above analysis is apparently due to the coal specimen having been accidentally soaked while *in transitu*.

It is clearly an excellent coal for domestic use, and, if it will make a firm coke, is a valuable fuel for gas works' use; the percentage of volatile matters being equal to the Connellsville coal, and fully equal or superior to the Reynoldsville coal percentage of gas.

An analysis of this same coal bed (and from this mine) made by Prof. C. F. Chandler (Feb. 10, 1876,) reads thus:

Volatile combustible matter,	31.70
Fixed carbon,	56.50
Ash,	9.85
Sulphur,	1.00
Water,	0.95
	100.00

This agrees almost perfectly with the analysis of Mr. McCreath, except that the coal not being wet, Prof. Chandler gets only the normal percentage of water.

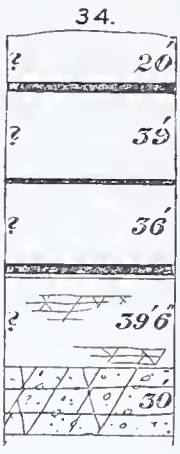
The conglomerate of XII shows below the coal (40 feet below) as a massive gray sandstone, containing numerous layers of white rounded quartz pebbles.

Report of Mr. Andrew Sherwood.

This Pine Creek region was examined by Mr. Andrew Sherwood in 1876, who thus reports the facts observed by him:

"The basin which I have described enters Potter county, as before stated, on the north side of Pine Creek, and crosses the North Branch above Kilbourn's Hotel, keeping on the north side of the West Branch. Two or three miles above the forks of Pine Creek are two considerable streams coming into the West Branch from the north—Whittemore Run and Beech Flat Brook. About two miles up Whittemore Run, on the west side of the right-hand fork, (or "draft," as it is here called,) I made the following observations:

Section of Coal Measures on the West Side of the Right-hand Draft of Whittemore Run.

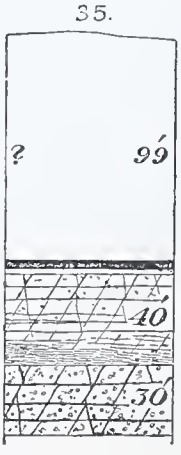


No.		
1.	Concealed from the top of the mountain,	20′ 0″
2.	*Coal*, thickness unknown, but the smut of which is 4 feet thick,	4′ 0″
3.	Concealed,	39′ 0″
4.	Coal,	2′ 0″
5.	Concealed,	36′ 0″
6.	*Coal*, into which a drift has been carried for fifty feet,	3′ 4″
7.	Fireclay,	2′ 0″
8.	Concealed; probably brownish S. S., becoming gray and dark-colored towards the top,	39′ 6″
9.	Millst'e Grit, a coarse hard, white and massive S. S., containing pebbles,	30′ 0″
	Total,	175′ 10″

About three-fourths of a mile from this spot, in an easterly direction, I saw a large spring cutting through No. 6. It is one of the finest natural exposures of coal in Northern Pennsylvania. The height of the hill at this point above the coal is one hundred and twelve feet. * * *

On the east side of the right-hand draft of Whittlemore Run, opposite the point where I made the foregoing section, I found the following beds :

Section of Coal Measures on the East Side of the Right-hand Draft of Whittemore Run.



No.		
1.	Concealed from the top of the mountain,	99′ 0″
2.	*Coal*,	3′ 0″
3.	Fireclay, filled with roots, leaves of *neuropteris*, &c.,	2′ 0″
4.	Brownish sandstone, changing to a gray and dark, slaty, sandy rock towards the top,	40′ 0″
5.	Millstone Grit,	30′ 0″
	Total,	174′ 0″

These facts agree closely with the observations made for the State Survey in 1877.

This same coal bed (the 3′ 2″ bed) has been opened for examination at numerous places in the region between Pine Creek Fork, on the East, towards Burrow's School House on the West, a distance of about 5 miles; it lies in the hills between the branches of Pine Creek, well up towards the hill tops, the elevated plateau under which it lies varying in width, ranging about 2 miles across in the centre of the basin; the basin points out to the East at the Forks of Pine Creek, and apparently on the West, at or about Burrow's School House.

The exact area of land underlaid by the coal could only be determined by running out the outcrop lines; where a coal lies so near to the hill tops a very slight widening out of valley sufficing to make great changes in acreage.

The basin lies well for mining; the coal could be easily attacked on Whittemore Run and Beech Flat Brook, and the valleys of these streams would an easy outlet to the West Branch of Pine Creek.

Taking 3 feet 2 inches to 3 feet 4 inches as the average thickness of the coal bed it will yield 5,000 tons to the acre.

Hitherto the region has been far removed from any railroad connection with a market.

The Jersey Shore and Pine Creek Railroad, upon which considerable work has been done, would pass directly by Gaines, and also by the Forks of Pine Creek, thus giving an outlet to the South to Williamsport, or to the Northwest to Buffalo and Canada.

And the proposed Geneva, Hornellsville and Pine Creek Railroad, if it should be constructed, would afford a direct route to Hornellsville, on the New York and Erie Railroad, and Geneva on the New York Central, thus throwing the coal by a short route into Central and Western New York State.

Character of the Gaines and Pine Creek Coals.

The analyses of the Gaines coal and the coal from the West Branch of Pine Creek are grouped below for convenience of reference:

	1.	2.	3.
Water,	3.260	3.070	0.95
Volatile matter,	27.860	30.970	31.70
Fixed carbon,	60.421	55.140	56.50
Sulphur,	.804	.975	1.00
Ash,	7.655	9.845	9.85
	100.000	100.000	100.000

No. 1. Knox & Billings Bed, Gaines, Tioga county.

No. 2. West Branch Pine Creek, Potter county.

No. 3. West Branch Pine Creek, Potter county. Analysed by Prof. C. F. Chandler.

It must be remembered that Nos. 1 and 2 were wet *in transitu*, and show, therefore, too high a percentage of water.

Throwing out the accidental impurities of sulphur, ash, and water, the coals show the following relationship of Volatile Hydrocarbons to Fixed Carbon:

1.	2.	3.
1—2.1687	1—1.7804	1—1.7823

And the ignitible constituents stand in the following proportion:

	1.	2.	3.
Vol. Hydrocarbons,	31.5588	35.9656	35.9411
Fixed carbon,	68.4412	64.0344	64.0589
	100·000	100.	100.

It will be at once seen that this coal is much higher in Hydrocarbons than the Blossburg or Barclay coal.

It is a *gas* coal, as well as a steam coal; and is almost identical in composition with the Reynoldsville coal from Jefferson county, which now is largely shipped to Buffalo for the gas coal trade along the lakes and in Canada.

One important question of a gas coal, namely, the character of the residual coke, this coal has not yet been tested for.

For all steam coal uses the Gaines coal can be compared with the Blossburg coal by examining the tables of Chapter XIII, of this report.

APPENDIX.

WHAT IS THE BEST OVEN FOR COKING COAL FOR FURNACE USE?

By Jno. Fulton, E. M.

General Mining Engineer, C. I. Co.
Cambria Iron and Steel Works,
Johnstown, *8, 18, '77.*

Prof. J. P. Lesley,
State Geologist:

Sir: In a recent communication from Franklin Platt, Esq., your Assistant Geologist in this district of the State Geological Survey, he indicates what he conceives to be a present want in the important industrial department of Coking Coals for blast furnace use,—*a definite and decided opinion of the kind of oven best adapted to this purpose;* or, as he writes:—"The general nature of everything in Report L, relating to Coking is in favor of the Beehive Oven; and yet it is not so clearly or decidedly in its favor as would be the case if the book was to be written, or revised, at this time."

The published paper on Coking grew out of an inquiry into the qualities of cokes used at the Iron and Steel Works of the Cambria Iron Company, at Johnstown, Penna., instituted by Hon. D. J. Morrell, the General Manager.

It is now nearly two years since that paper was written, during which time considerable facts have been collated bearing on this important matter,—the make of coke for blast furnace use. In the former article, the statistics from the three typical methods of coking were submitted, leaving the reader, in the absence of definite proof, to draw his

own inferences as to the best kind of oven in the production of good metallurgical coke.

The present paper is, therefore, designed as a supplement to the former paper on the methods of coking, published in Report L of the Second Geological Survey of Pennsylvania,—and intended to satisfy, as far as ascertained facts will permit, Mr. Platt's effort to have the best coking oven eminently distinguished.

From the facts hitherto submitted it has been definitely settled, that certain qualities of coal are the prime elements in the production of good furnace coke. The methods of coking are secondary. If the coal is unfit for making good coke, either from impurities or lack of bituminous matter, no treatment in its coking can correct these normal defects. But, other conditions being equal, the mode of coking exerts a decided influence on the physical structure of the coke, adding to or taking from its calorific value as a furnace fuel.

It is remarkable, however, that the most desirable coking coals inherit in their normal composition the elements which give their cokes, under right oven treatment, the best physical structure for maximum calorific energy and economy in blast furnace use.

That there is a very wide range of differences in the calorific value of coals, in their application to special purposes, has been fully demonstrated. Rich bituminous coals that would give satisfactory results in generating steam, would be worthless in a blast furnace.

Hence, a careful study of each variety of coal has been made, in order that it may be applied in such a manner and to such uses as will insure the greatest efficiency and economy. In this intelligent application of particular varieties of coals to especial purposes, great care has also been taken in the examination of their chemical constituents, physical structure and calorific values. Whilst this triple attention has been given to coals and their right application clearly made out, coke has been regarded simply in two aspects,—its hardness and purity.

If it was "*dense*" with a "silvery luster" and "sonor-

ous," it was received without further scrutiny,—and no distinction made between cokes approximating these *standard* requirements. Coke was coke. And what difference should it make in furnace work if one coke differed in physical structure from another, when both inherited nearly equal volumes of carbon, ash and sulphur? But results, obtained from furnace work, clearly showed the existence of wide differences in their calorific values,—differences so marked as to make questionable the value of certain qualities of coke for furnace work.

Take, for instance, the analyses of the following cokes for blast furnace use :

Table A.

	I.	II.	III.	IV.	V.	Average Standard.
Water, ...	0.030	. . . .	. . . .	. . . .	0.800	0.35
Volatile Matter, . .	0.460	. . . .	. . . .	. . . .	. . . .	0.46
Fixed Carbon, . . .	89.576	87.58	90.48	89.28	91.106	89.06
Sulphur, ...	0.821	1.06	0.56	1.06	0.544	0.80
Ash, ...	9.113	11.36	8.96	9.66	7.550	9.33
	100.	100.	100.	100.	100.	100.

Manifestly there is little difference in the chemical elements of these cokes; from which to infer wide differences in their calorific values in furnace work.

Cokes I and IV were made in Beehive ovens,—I from coal as it came out of the mine, and IV from washed coal. These are the best qualities of cokes.

Coke II is made in Belgian ovens from coal as mined,—it also is of the best quality.

Coke III is made from washed coal in Belgian ovens. It could not be advantageously used alone in furnaces running on Bessemer pig iron. About 20 to 30 per cent. of it can be used as a mixture with Cokes I, II, IV or V. Increasing its use over these proportions will induce a cooling of the furnace with unsatisfactory work. This has been definitely settled by intelligent tests in blast furnace.

James J. Fronheiser, Esq., Superintendent of Furnaces,

C. I. Co., has recently made some interesting comparative tests of coke in one of the furnaces under his direction, at Conemaugh. This rather small furnace was run for a week on Coke I, in table A, which inherits an open cellular structure. The blast was heated to 800° F., and driven at the rate of 2600 cubic feet per minute. The ores used were mainly from Lake Superior, with some native hematite and Spanish mixtures, producing for the week 156 tons of good Bessemer pig iron.

The following week the furnace was run on a fuel mixture of $\frac{1}{4}$ Coke I, and $\frac{3}{4}$ of a coke somewhat *denser in structure* than Coke I, but in every other respect its equal. The furnace stock orherwise precisely equal during both tests, the blast was increased in volume to 3250 cubic feet per minute, to meet the increased density of the fuel. The result was a week's make of 145 tons of good Bessemer pig iron.

The consumption of coke in both weeks was 1.29 tons to 1 ton pig metal. The cokes were carefully weighed dnring both tests. Both cokes were made in Beehive Ovens.

The resnlts show that under the best conditions, with the column of blast proportioned to the density of the cokes used, there is a direct loss in a week's work of 11 tons of metal, or $7\frac{1}{2}$ per cent., nearly.

The test was made mainly to determine whether the proportioning of blast to the density of each quality of coke, would produce equal results. Hence, equal weights of coke to 1 ton of pig were used. The question of the relative economy of these cokes, in the quantity of each required to smelt 1 ton of pig iron was not entered into.

The test exhibits a loss of product, by the languid action of this dense coke, which, considered alone, would reduce its value from that of Coke I at least 11 per cent. *It indicates also the loss made by using in mixture in a furnace cokes of different physical properties.*

Direct tests were made at the furnaces of the Kemble Coal and Iron Co., in the Broad Top coal region, in December last, by William Lander, Esq., General Superintendent, to determine the relative calorific values of cokes made in Beehive and Gobeit ovens, using the same quality of coal in

each kind of oven. The furnace in which the tests were made is 14′x60′, with modern blowing machinery and hot blast oven. The ores are from the Clinton groupe, (No. V,) well known as the Juniata Fossil Ore, containing 30± per cent. of metallic iron. The coke is made in Beehive ovens.

Previous to this test a few Gobiet ovens were erected, from which the coke was obtained for this purpose. The increased density of coke made in this kind of oven was very manifest.

It was found that with careful management in both trials it required 2300 pounds of Gobeit coke to carry the same furnace burden as 1900 pounds of Beehive coke.

Mr. Lauder writes: "I should like to hear from you on the subject. I confess I am surprised at the results. While this coke was on the furnace it took 5196 pounds to 1 ton of pig iron. With the Beehive coke, 4156 pounds for the same work."

The loss, per ton of pig iron made, is 1040 pounds of coke, or 20 per cent. If the furnace makes 250 tons a week, the loss would be 115½ tons of coke, at $2.25=$259.87 per week.

On the other side two claims are made—one for the economy of labor in the Gobeit oven, the other for a larger per centage of coke from the coal.

It will be shown subsequently that an economy of 12 cents per ton does exist under the first claim, and under the second an increase in coke of 14.3 per cent., nearly—taking the product of Beehive at 63 per cent., and the Gobeit oven at 72 per cent.

Taking the weekly make of pig metal, as before, at 250 tons, and using 1.85 tons of coke to 1 ton pig iron, will require 462½ tons a week.

Then 462½ tons, saving 12 cents per ton, ...	$55.50
Increase of coke of Gobeit oven, 14.3 per cent.=66 tons, @ $2.25, ...	148.50
Total, ...	$204.00

The actual loss per week would be $259.87, less $204.00,

equal $55.87. With the dense coke the furnace worked badly, producing an inferior pig iron.

In this case difference in the densities of the two cokes was much greater than in the cokes used at Conemaugh Furnace trials; hence the increased difference in results. Doubtless the Gobeit oven in the latter case experienced some difficulty in coking a washed coal of rather moderate per centage of bituminous matter, making the ovens run cold, and intensifying the dense structure of the coke.

But the difference, in practical furnace work, by cokes of varying physical structure, is clearly made out.

These tests have been corroborated by others pursuing the same general inquiries, but it is presumed that they are sufficient to establish the points raised in the investigation of this Coke fuel question,—*the direct effect of its physical structure on furnace work.*

In pursuing this inquiry it is important to qualify the conditions of its use in furnace work. The advantages of large cellular coke in this respect has been fully illustrated. This result assures the well known principles in furnace practice, that the more cellular the coke the smaller the volume of blast air necessary to burn it, and that the rapidity of combustion is in direct proportion to the amount of surface exposed to the action of the oxygen of the blast air. The best coke for furnace fuel should therefore possess the largest cell structure with the *hardest* cell walls possible in coke. Many cokes of medium cell structure are compensated by a columnar structure in coking and the consequent breaking up into small pieces. The undesirable cokes are therefore: 1st, Coke of a soft quality and dense physical structure; and 2d, Coke of soft or hard quality made dense by the method of coking.

There may be some exceptions in favor of a moderately hard dense coke in its use as a mixture in anthracite furnaces, as by its *density* it will bear a pressure of blast nearly equal to anthracite coal and coöperate with the latter in giving out its heat.

A mixture of this kind of coke of $\frac{1}{3}$ to $\frac{2}{3}$ of anthracite coal has been found to work advantageously in keeping the

furnace open and energysing the anthracite fuel. This exception in the use of dense hard coke in conjunction with anthracite coal does not change or modify the general law governing the production of cellular coke for blast furnace use. It only shows that medium dense coke helps anthracite coal in furnace work,—and the increased calorific energy which its presence induces would probably be still more marked in anthracite furnaces of moderate height.

The principle which requires hard cellular coke fuel for blast furnace use is in requiring a minimum volume of blast in supplying the oxygen demanded in the combustion of the fuel.

If the heat at the tuyeres in a blast furnace is taken at 3000° F. and the blast air forced through the tuyeres at 1000° F.,—then it is evident that the greater the volume of blast air necessary in the combustion of the fuel (above what is absolutely required for the oxidation of the carbon of the fuel in its best physical condition) the greater will be the cooling effect of this excess of blast air.

Hence the prime requirement in producing coke with the largest possible cell structure, so as to afford the greatest surface to the action of the blast air,—reducing the latter to its minimum volume. And in this it appears will be found the real difference of coke and anthracite coal in furnace use. Not that there is any marked difference in the heat evolved from their respective carbons; but in the superior carolific energy of the former in its rapidity and economy of combustion produced by its physical structure.

The requirements of a good coke therefore are: 1st, purity; 2nd, hardness of body; 3rd, the largest possible cell structure, limited only by its capacity to sustain the furnace burden.

Two questions follow: What is the best quality of coal for making coke? and what is the best oven for coking for furnace use?

I. *What is the best quality of coal for making coke for bast furnace use?*

The practical answer to the question is, the analyses of coals that are well known to produce the best cokes.

Table B—Analyses of typical Coals that make the best Coke.

	Connellsville Coking Coal. (McCreath.)	Bennington Seam B. (McCreath.)	Lilly's station—Coal E. (McCreath.)	Broad Top. Kelly—E. K. C. & I. Co. (Morrell.)	Ohio—Hocking Valley, Bailey's Run. (Prof. Wormly.)	Average Standard.
Water, ...	1.260	0.910	0.715	0.82	3.80	1.500
Volatile Matter, ...	30.107	26.340	22.250	18.86	32.77	26.060
Fixed Carbon, ...	59.616	64.373	70.518	71.12	58.10	64.750
Sulphur, ...	0.784	1.792	1.459	1.70	1.15	1.380
Ash, ...	8.233	6.585	5.058	7.50	4.18	6.310
	100.	100.	100.	100.	100.	100.

This table shows very clearly the essential requisites of coals for making first-class coke.

The relationship of volatile matter to the fixed carbon, as shown in the table, is very suggestive; although the precise *agency* of the former, in producing large cellular coke, is not yet so clearly made out.

The average percentage of fixed carbon in the coals of table B is 64.75, the volatile matter 26.23 per cent., which can be regarded as constituting an excellent coal for coking. Any excess of volatile matter over 25 per cent. is not a necessity, whilst on the other side, any large reduction from this volume must be compensated, in supplying heat for coking, at the expense of the fixed carbon, especially in cases where the coal has to be washed.

If 25 per cent. of volatile matter is taken as the standard, it will subsequently be shown that 17 per cent. would constitute a minimum in useful or economical coking; but no good furnace coke is known to the writer to have been made from coal from this small ratio of volatile matter.

That hard, dense coke can be made from such coal is a fact fully proved,—and that such coke is chemically pure for any kind of furnace work is equally well established.

TABLE C.—*Analyses illustrating the family of Dry Coking Coals, from the Lower Productive Coal Measures of the Allegheny Coal Field:*

	Smith & Co. (McCreath.)	Bed B. Unwashed. (McCreath.)	Bed B. Washed. (Morrell.)
Water at 225° F.,	.615	1.185	2.50
Volatile matter,	17.935	16.540	20.50
Fixed carbon,	76.503	74.456	73.24
Sulphur,	.602	1.860	.43
Ash,	4.345	5.959	3.33
	100.	100.	100.

Coke made from the above peculiar class of coals, whilst possessing all the essential elements of a first class fuel, yet because of very porous or *dense physical structure*, it is found in practice undesirable for furnace use. This has reference alone to the excessive dense cokes. Cokes approaching anthracite coal in closeness of structure, but unmodified by the character of the latter in breaking up in small pieces in furnace work.

With the moderately dense cokes the blast can be proportioned to their density. The main result in the use of coke over standard density will be in the reduction of the make of metal. With very dense coke the result is not only in loss of make of metal, but in its inferior quality and general unsatisfactory working of the furnace from its characteristic soft cell walls.

II. *What is the best oven for coking for blast furnace use?*

That the mode of coking exerts a very important, though secondary influence, on the *physical character*, uniformity of quality, and dryness of the coke, has been very fully determined in furnace work. But it is questionable whether sufficient attention has thus far been given to the *physical structure* of the cokes as affected by each class of coke ovens.

The three typical families of coke ovens, the Bakers or Beehive, the Coppee, Belgian or François, and the Appolt,

all testify to efforts in the production of coke from widely different qualities of coals, without any design at enlarging or modifying the cell structure, or volatilizing a maximum of sulphur, with an objective aim at the largest percentage of product, and economy of work.

The action of each system on the *density* of the coke will be readily understood, if we conceive a brick, laid flat, to illustrate the section of chamber in the Beehive class of ovens, with its necessary shallow charge, minimum pressure in coking, and consequent maximum cellular product of coke.

If a brick is laid on its edge, it will show very accurately the posture and condition of the chamber in the Gobeit, Coppee, Belgian or François ovens, with the necessary *pressure* induced by the increased depth of charge, producing an increased density in coke.

The Appolt oven is made plain, by setting the brick on end, producing the maximum pressure on its charge, and consequently the densest coke.

Mr. I. L. Bell, however, points out the difference of the physical character of coke and its influence on furnace operations, in page 315 of his work on "The Chemical Phenomena of Iron Smelting." Reviewing the results of coke in furnace work, made in ovens of ancient and modern plans, he says: "My firm has tried these plans" (Belgian or François ovens), "but found the useful effect in the furnaces inferior to that obtained in the ordinary way (Beehives).

In consequence of this, all the more recently erected ovens have been constructed upon the old fashion; and I have endeavored to ascertain what are the circumstances which reduce the value of the commodity made according to the more modern improvements below that made in the more simple oven."*

*Hon. D. J. Morrell, who has just returned from Europe, (Oct. 1878) visited when in England, the extensive iron works of Mr. I. L. Bell's firm. He found the coke being prepared in extensive and complete *Beehive ovens*. The charge to each oven was six tons of coal yielding 3½ tons of excellent coke, (58.2 per cent).

The practice and authority of the author of *Chemical Phenomena of Iron Smelting* ore on the side *Beehive Ovens.*,

In pursuing this inquiry, he gives the results of several experiments illustrating the action of hot carbonic acid on the carbon of cokes of different physical structure, proving that it is affected in widely different degrees by the solvent power of the carbonic acid gas.

In other words, that coke can be made too hard or dense as well as too soft and open for the most useful effect in furnace operations. That a coke of intermediate physical structure, between the above, is the most desirable in yielding its heat readily, efficiently, and uniformly, thus maintaining the train of operations in the chemical reactions of the furnace which are so essential to the best results in its operations.

"Experiment 706. 2¼ grammes of hard coke, previously exposed for two hours in a covered crucible to a high temperature, was placed in a combustion tube. All air being expelled from the apparatus, a stream of thoroughly dried C O_2 was passed over the coke for 15 minutes at a red heat, and for 35 minutes at bright red (maximum of a Hofman's double furnace). Two litres of C O_2 were passed over the coke, and from this only 26 c c s of C O were collected, the remainder of the C O being unchanged."

"Exp. 708. Hard coke, pulverized to size of mustard seed, exposed at a temperature of melting zinc for three quarters of an hour to a current of C O_2, gave a mere trace of C O."

"Exp. 709. Soft coke, similarly treated as previous exp. (708), in 1¼ hours, gave 92 c c s of C O, determined by explosion with O, and absorption by K H O."

These experiments indicate very decidedly the action of carbonic acid gas on the three conditions of cokes submitted to these tests. They exhibit more especially the most desirable condition of coke for furnace use. They do not, however, embrace a wide enough range in the investigation of the physical structure of coke, for "hard coke" and "soft coke" are simply relative terms, indicating the completeness or incompleteness of the operation of coking. Reducing or pulverizing each quality of coke to the size of mustard seed, cannot represent related conditions in actual

work in the furnace, for the undesireableness of most of the dense cokes consists in part of their production in large lumps, whilst the desirable coke is produced in moderately diminutive pieces.

The prominent and conclusive fact is made out, that the make of coke in one class of ovens is not found useful in a degree warranted by the nature of its constituents, and that a different kind of oven, treating the same coal, produced a coke giving entirely satisfactory results in furnace work, under precisely similar conditions with the former.

The extremely soft, or partially prepared coke, called "black ends," would undoubtedly cause the furnace to work disadvantageonsly, in loss of heat by its dissolution too high in the stack.

This indicates the necessity of the uniformity of quality in the coking of fuel for persistent useful work in furnace operations.

The examples of the undesirable properties of dense coke in Conemaugh and Kemble furnaces, are sustained by very wide experiences in using too dense a fuel.

Mr. P. Doyle, L. C. E., in the "Colliery Guardian" of February last, indicates an effort recently made in British India to interest the capitalists of Bengal in the development of the native iron manufacture. In this connection the quality of coke has been entered into. "It is satisfactory to learn that in order to meet the demand which must naturally ensue, the principal coal companies in this part of India are devoting a great deal of attention to the manufacture of coke. Prominent among the companies is, of course, the East India Railway, whose resources in this respect may be approximated at nearly 50 tons per day. The quality of this coke, although considered the best in India, is not all that could be desired. Its great fault is excessive *density*, which renders it almost incombustible at ordinary red heat. The analysis yields:

Carbon,	84.09
Ash,	15.66
Sulphur,	.25
Moisture,	None.
	100.

It is added, "the defect is one that can be easily rectified," and here, just on the threshold of the most interesting inquiry, the correspondent suddenly stops! As the composition of the coal from which the coke was made is not given, it is impossible to estimate whether the objectionable *density* of the latter can be "rectified" or not. A reduction of its ash is evidently required.

A gentleman from South Russia visited the Cambria Iron Works during the past centennial year. He was in the pursuit of knowledge. A furnace with which he is connected had been put in blast, with hard Donetz anthracite coal as a fuel, composed as follows: Carbon, 95; ash, 3, and volatile matter, 2. This fuel was charged into the furnace in great "*chunks*" of one half ton or more. Under the action of heat these did not break up or decripitate, hence, wide spaces were left open for avenues to blowers, impinging on the furnace lining, and cutting it out in a little over a week's blast.

The trial was made a second time, after enveloping the new lining of furnace in a mammoth tuyere. This time the effort was continued over two weeks, terminating in the same disastrous results as in the former case.

This gentleman was advised to import an American "Coal Breaker," or procure a comprehensive assortment of sledges and hammers to break the coal into small pieces before introducing it into the furnace.

Undoubtedly the same experience would have been encountered in the use of the American variety, but for the property the latter possesses of decrepitating freely on exposure to furnace heat, thus exposing enlarged surface space to the action of the reducing gasses, and enabling it to be used with a heavy column of blast.

The breaking of larger pieces of all cokes inclined to density of physical structure has been found beneficial in furnace use. In one case a saving of 12 per cent. of fuel was obtained by breaking up the larger pieces. The denser the coke, the smaller it should be broken, in preparing it for the blast furnace.

It has been determined that the best cokes for furnace

use inherit a physical structure having the cell space to the whole mass, in the ratio of 38 to 62; and that the average of the series of best cokes would give as a standard the cell space of 36 to 64 of coke. It is also important that the cell spaces are large and well defined—easily distinguished from diminutive cells or pores.

The latter may occupy as large a space in the aggregate as the former, and yet be undesirably *dense*.

The best quality of Connellsville coal, treated in the Belgian ovens of the Cambria Iron Company, produced a coke of *very objectionable density*, especially in the *bottom* and *middle* of the charge.

The effects of the pressure, in the deep charges of this family of ovens, on the density of coke has been observed. It increases from a cell space ratio at bottom of 26 to the standard average of 36 on the section, on top.

This is very definitely shown in the coke made in the experimental Gobeit ovens, at the Kemble Furnaces, in the Broad Top Coal Region.

In coking in the primitive pits or mounds, a very full cellular structure is developed—fully equal to the Beehive in this respect. There are, however, two objections to this mode of coking: 1st. It produces irregular work, a portion of its coke is soft or "black ends;" and, 2nd. That it is the most expensive of the systems under review. For uniform, economical work, in coking coal for blast furnace use, it cannot be strongly recommend. Yet under careful management, in mild dry weather, it has given results, on the whole, fairly satisfactory.

The inquiry as to the best *oven*, will be confined to a comparison of the Beehive and Belgian.

The Appolt being regarded as planned for peculiar cases which are not embraced in the limits of the present investigation.

The advantages of the Beehive are mainly as follows: 1st. It produces from the coal the best possible physical structure of coke; 2nd. It yields a uniform quality of coke; 3d. Its coke watered out in the oven is produced in the driest condition; 4th. In rabbling it out it is separated

into diminutive pieces; and 5th. The operation of coking in it is simple, and the cost of oven and repairs moderate.

The Belgian or François oven has its advantages: 1st. It produces a uniform quality of coke; and 2d. It is the most economical method of coking.

Its disadvantages consist mainly, with the ordinary coking coals, in making a *dense* coke. It requires skill in its coking operations. It requires its coke to be quenched outside in a clumsy manner, producing a damp fuel. Its cost is large, but its repairs moderate.

It is only especially adapted to the family of coals demanding pressure in coking, to prevent too inflated a physical structure, and to the peculiar cases hitherto noticed, consisting of coals holding a minimum of volatile matter and requiring washing. It may be urged, however, that the coke from this class of coals, holding a small percentage of the cell making matter in its composition, is so *dense* as to be undesirable for metallurgical purposes, and doubtless this is true. But the question arises, whether mixtures of cokes of different densities in a blast furnace are economical, since the blast cannot be proportioned to the densities of the fuel and must therefore be a compromise with its consequent waste. But in the coking of such coal, a mixture of more bituminous coal might be introduced, enabling it to be coked in Beehive ovens with an improved open structure of coke.

The relative cost of making coke in each kind of oven is hereby given, with original cost of ovens and annual cost of repairs. The estimate contemplates banks of ovens to produce 100 tons of coke per day or 30,000 tons per year. Coal at $1 per ton delivered at ovens.

Beehive Ovens.

80 ovens at $200=	$16,000
Interest on investment 10 per cent. per annum .	1,600
Annual repairs and renewals at $10=	800

Then $\frac{\$2400}{30{,}000 \text{ tons.}}$ = 8 cents per ton of coke.

Cost of Coal and Coking.

1.60 tons of coal @ $1 per ton	$1 60
Labor at ovens, charging and drawing	27
Interest on cost of ovens and annual repairs . .	8
Coal, $1 60; coking, &c., 35 cents. Total= . .	$1 95

Belgian Ovens.

65 Ovens at $700 each	$45,000
Engine for pushing coke out of ovens	3,000
Annual repairs to engine	50
Tracks for engine	300
Annual repairs to ovens	310

Annual interest on investment ($48,800) at 10 per cent., $4,880.

Then $4,800+$310+$50=$\frac{\$5,240}{30,000 \text{ tons.}}$=17½ cents nearly.

Cost of Coal and Coking.

Coal 1.42 tons @ $1 per ton	$1 42
Labor at ovens, charging, luting, pushing, &c. .	23½
Interest on cost of ovens and annual repairs . .	17½
Coal, $1 42; coking, &c., $0 41. Total= . . .	$1 83

The Belgian plant of ovens is the more costly in construction, but less expensive in repairs and coking.

The economy in this class of ovens, consists in the saving in coal to make 1 ton of coke; the saving in the work of discharging the coke out of ovens and in their annual repairs.

The Beehive oven is less costly in construction but more expensive in annual repairs. Regarding the two systems in the aspect of absolute economy, embracing the interest of invested capital in their construction, with annual repairs of each, and without any reference to the value of the coke made by each kind of oven, the Belgian exhibits an economy of 12 cents per ton of coke in its favor.

But, estimating the ultimate results of each quality of

coke, in blast furnace work, and embracing all the factors demanded in its physical and chemical condition to insure uniform work, maximum calorific energy and economy, the *Beehive* oven is regarded as possessing the greater number of good properties. That it is susceptible of improvement is self-evident, in the utilization of expelled gases, especially at the commencement of the operation of coking, by introducing flues under the floor of the oven. But in all subsequent changes, the main principles of Beehive coke making should be retained—shallow charges, uniform work, and quenching the coke so as to produce it crispand dry.

The Belgian or François oven will retain its place of usefulness in coking certain qualities of coals: (*a*) The very pitchy or bituminous coals which agglutinate readily and swell in bubbles of abnormal size.

(*b*) The dry burning coals of the north west and west, known generally as "block coals."

(*c*) And in coking a third class of coals, it may be found a necessity—the coals that are low in volatile matter, 17 per cent.±. If these are found in a sufficiently pure state to be coked without washing, then the Beehive oven would be the proper method of treatment; but when they require washing, and are charged into the oven in a damp condition, the Belgian oven alone, it is believed, could support the necessary heat by its swift method of discharge of coke and immediate charge of coal into the hot oven chamber.

In the work of comparing the calorific values of the several qualities of cokes, by the "Bell Standard," the make of 1 ton of No. 3 pig iron from 40 per cent. Cleveland iron stone, with 2.408 pounds (1.075 tons) of coke, and blast heat at 932° F., it will be evident that great modifications will be required in the amount of fuel per ton for smelting the several qualities of iron ores, and that this quantity of fuel is not alone determined by the chemical composition of the ores, or their richness in iron, but also by their *molecular structures*. In the pursuit of this inquiry, an important member is greatly needed—the "co-efficient of fusibility" of each quality of the most useful and com-

monly used iron ores, in the heat units required for the reduction of a fixed quantity of each.

The whole matter of the selection and right preparation of mineral fuel for blast furnace operations, at this time, when the rapidly increasing use of coke is elevating its manufacture amongst the important national industries, becomes a study of the utmost importance, because of its prime influence not only on the quality and economy of the pig metal, but on the improved qualities of its widely extended products in iron and steel, enhancing their values in home use, and enabling the manufacturer to enlarge his operations by a successful competition in the marts of the world.

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Devonian Sections East and West of the Tioga River.

(made in 1841, and published in Final Report, Vol. I. p. 310.)

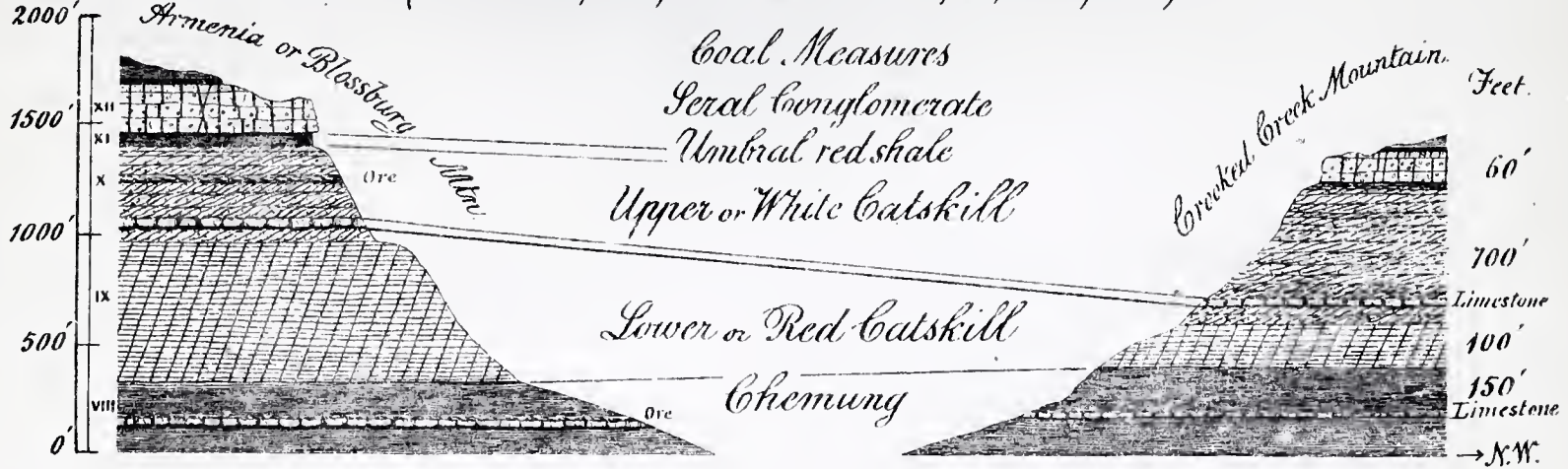

Diagram Section in Bradford Co Pa.

Diagram Section in Tioga Co. Pa.

Note. These diagrams do not represent the actual heights of the Towanda and Blossburg mountains, as such; but the several average thicknesses of the formations (VIII, IX, X, XI, XII,) measured at right angles to the dip; and they include with the rocks of the mountain all the rocks of the valley to the crown of the anticlinal. The spectator is supposed to look from the northeast

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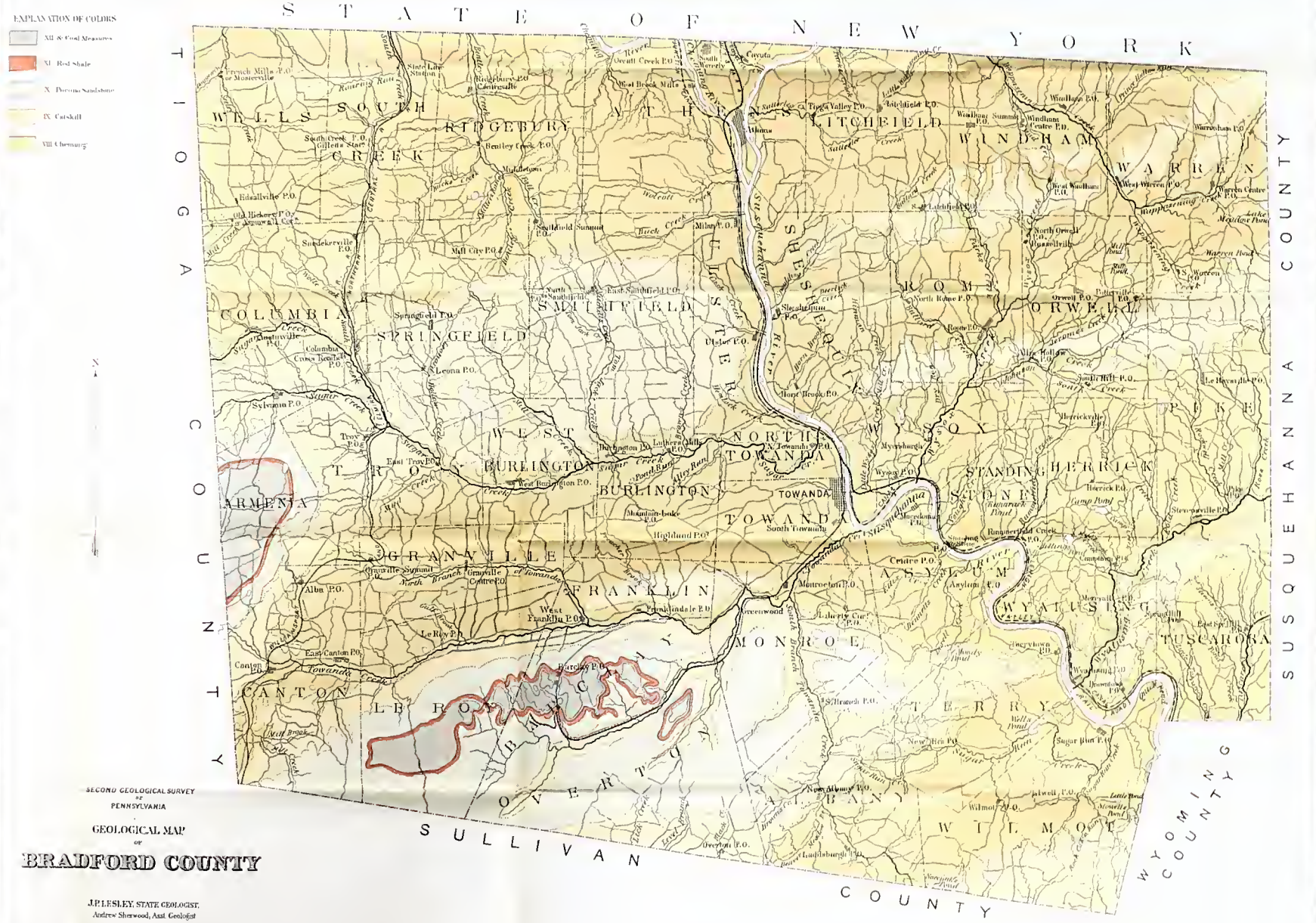
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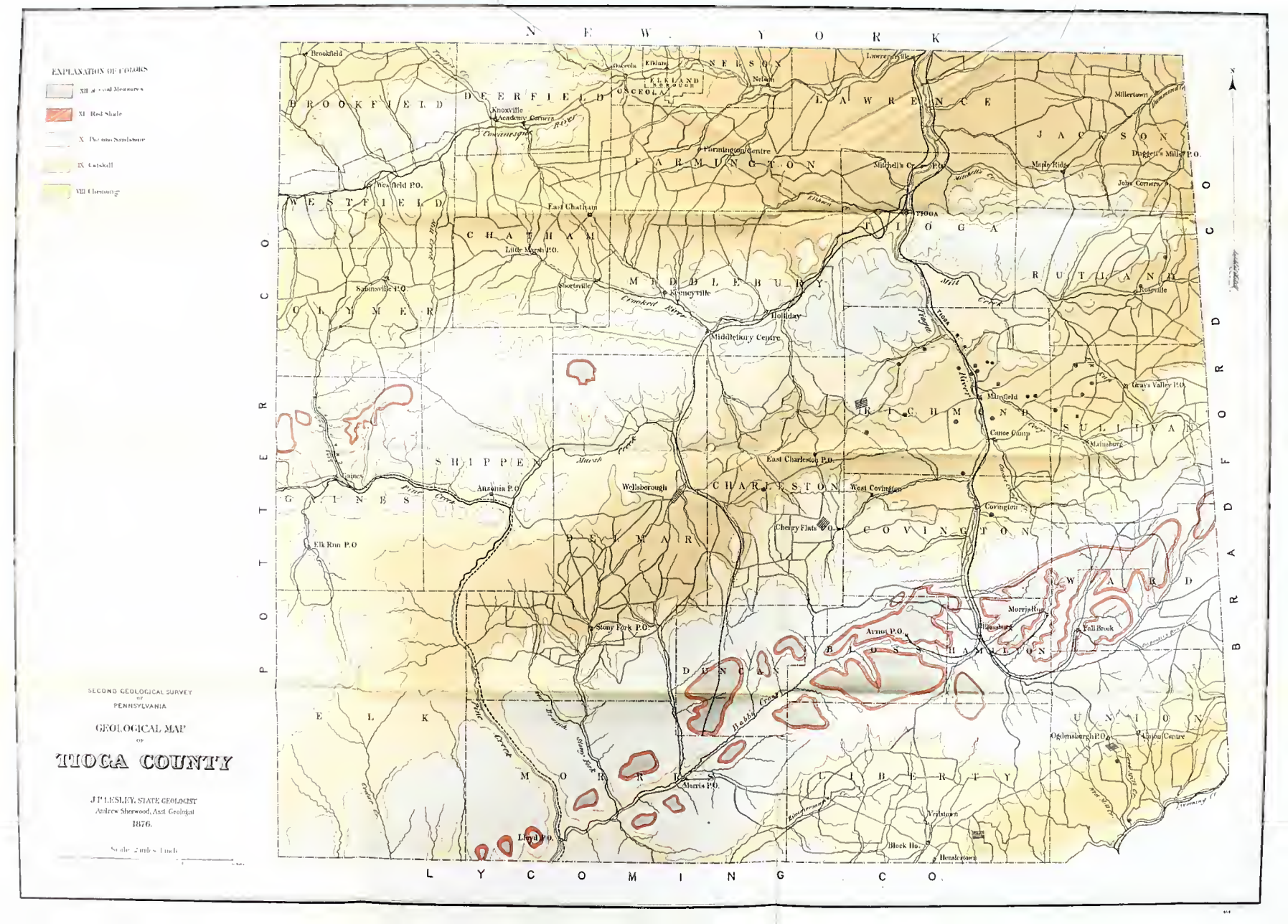
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